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COVER PICTURE

Welding in the fuel charge nozzles on the bottom head of Hunterston's reactor B pressure vessel.

Nuclear Power

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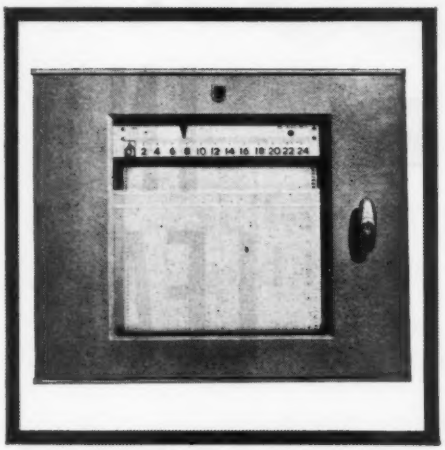

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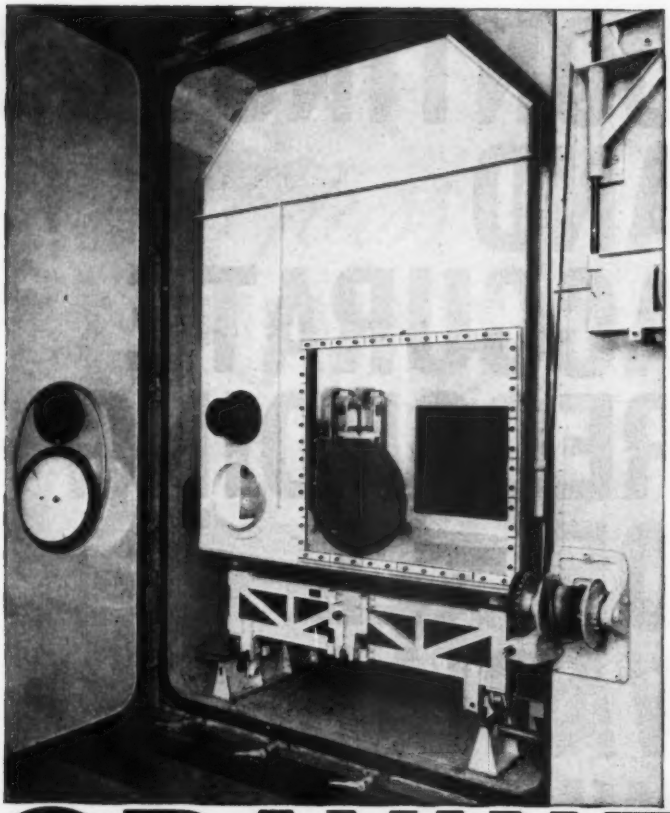

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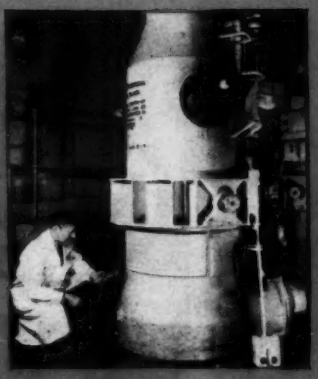

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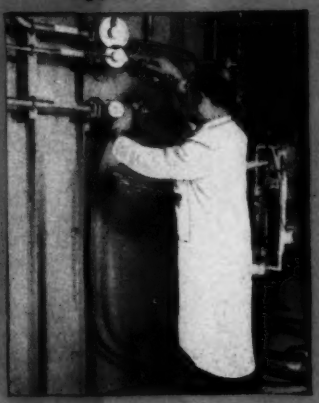

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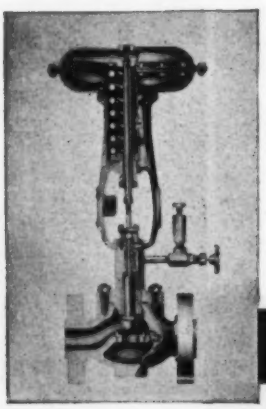

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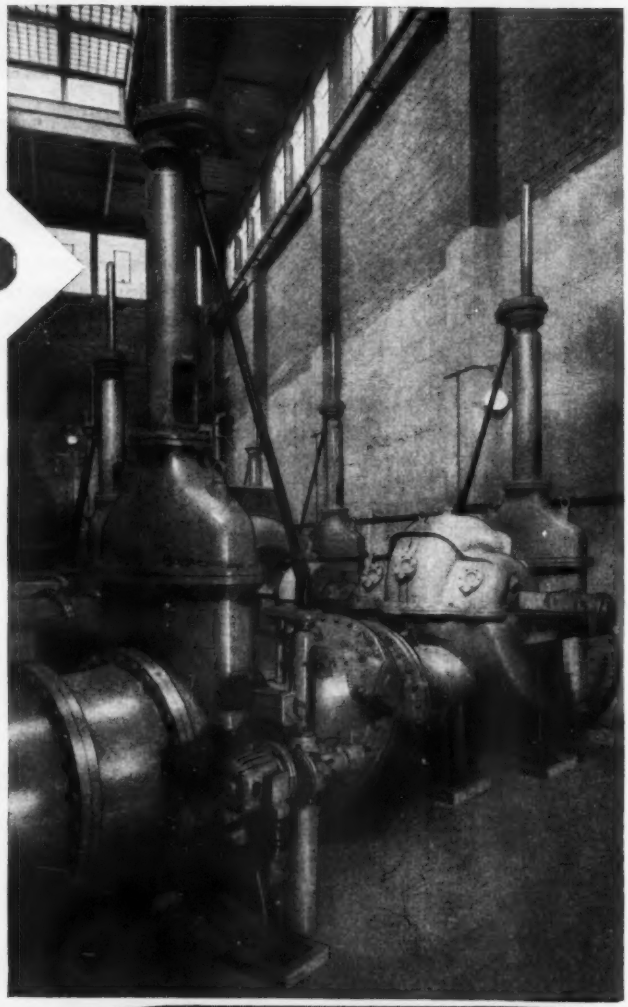

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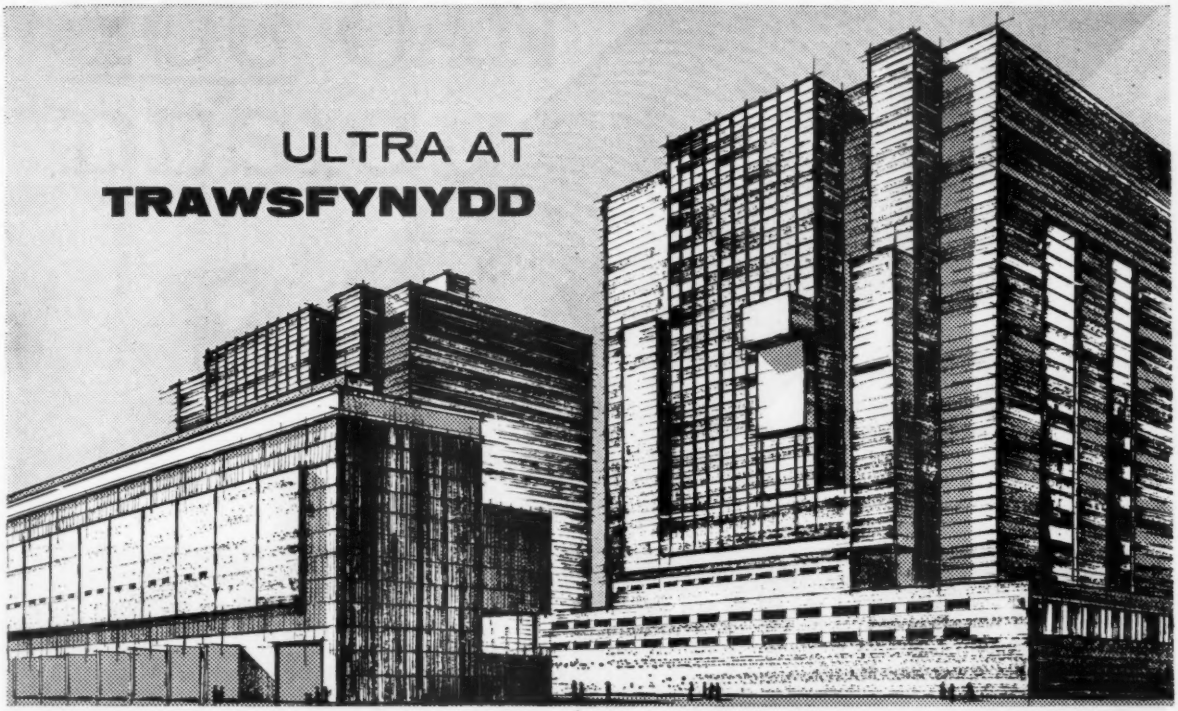

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The Ultra sector servo control system has been specified for the Trawsfynydd reactor installation being built by the Atomic Power Construction Company on behalf of the Central Electricity Generating Board. Ultra Electronics Limited have specialised experience in the field of servo systems for the close control of combustion in gas turbine engines; this they have successfully applied to the development of equipment for the temperature control of nuclear reactors. In more detail, this specialised experience covers:

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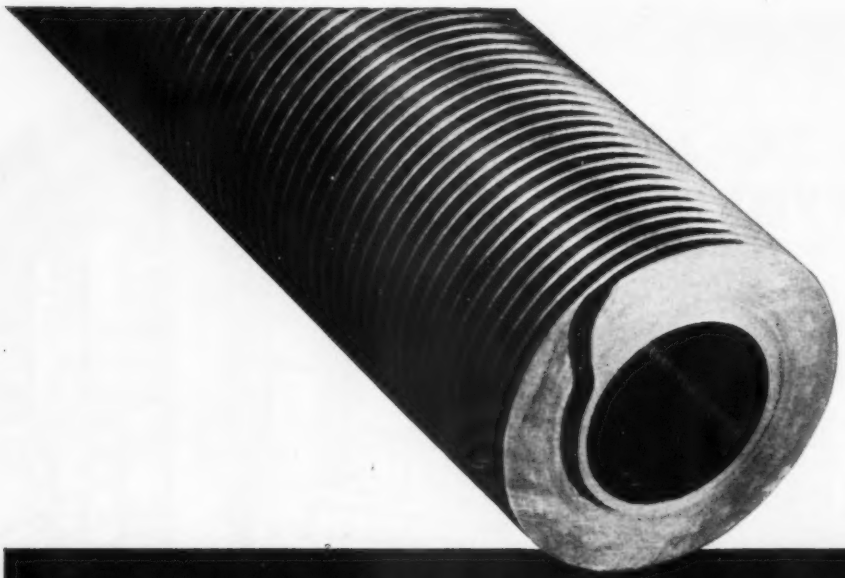

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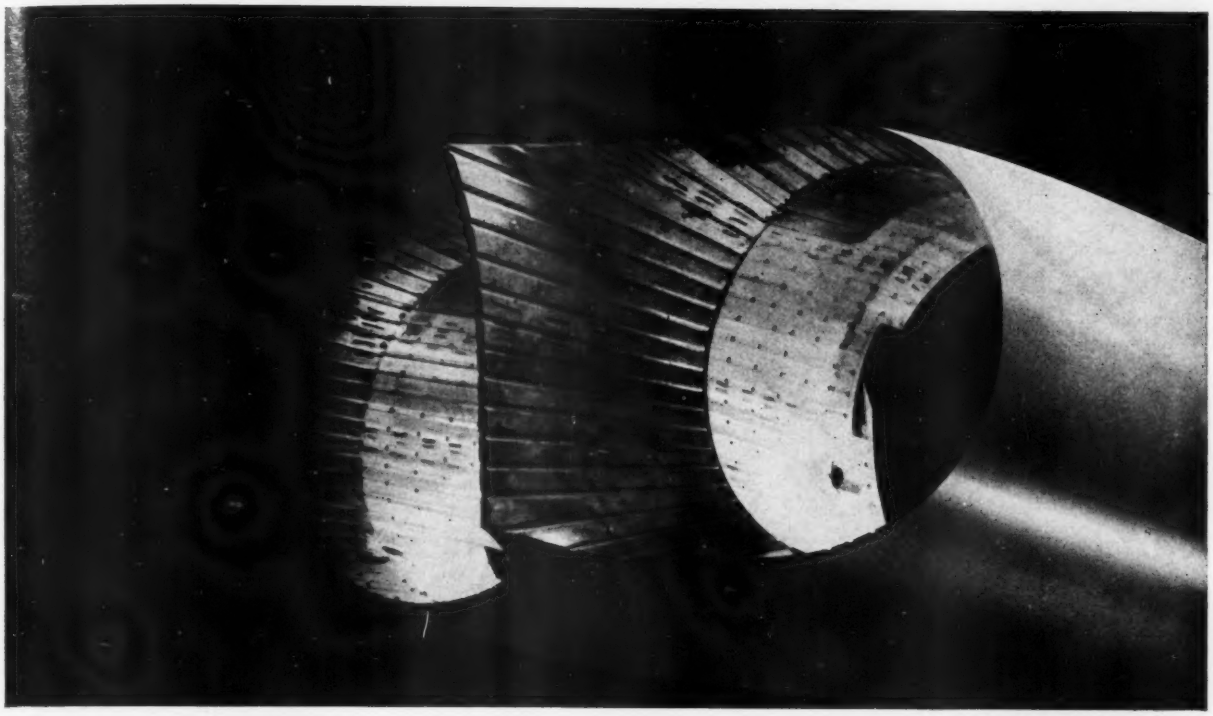

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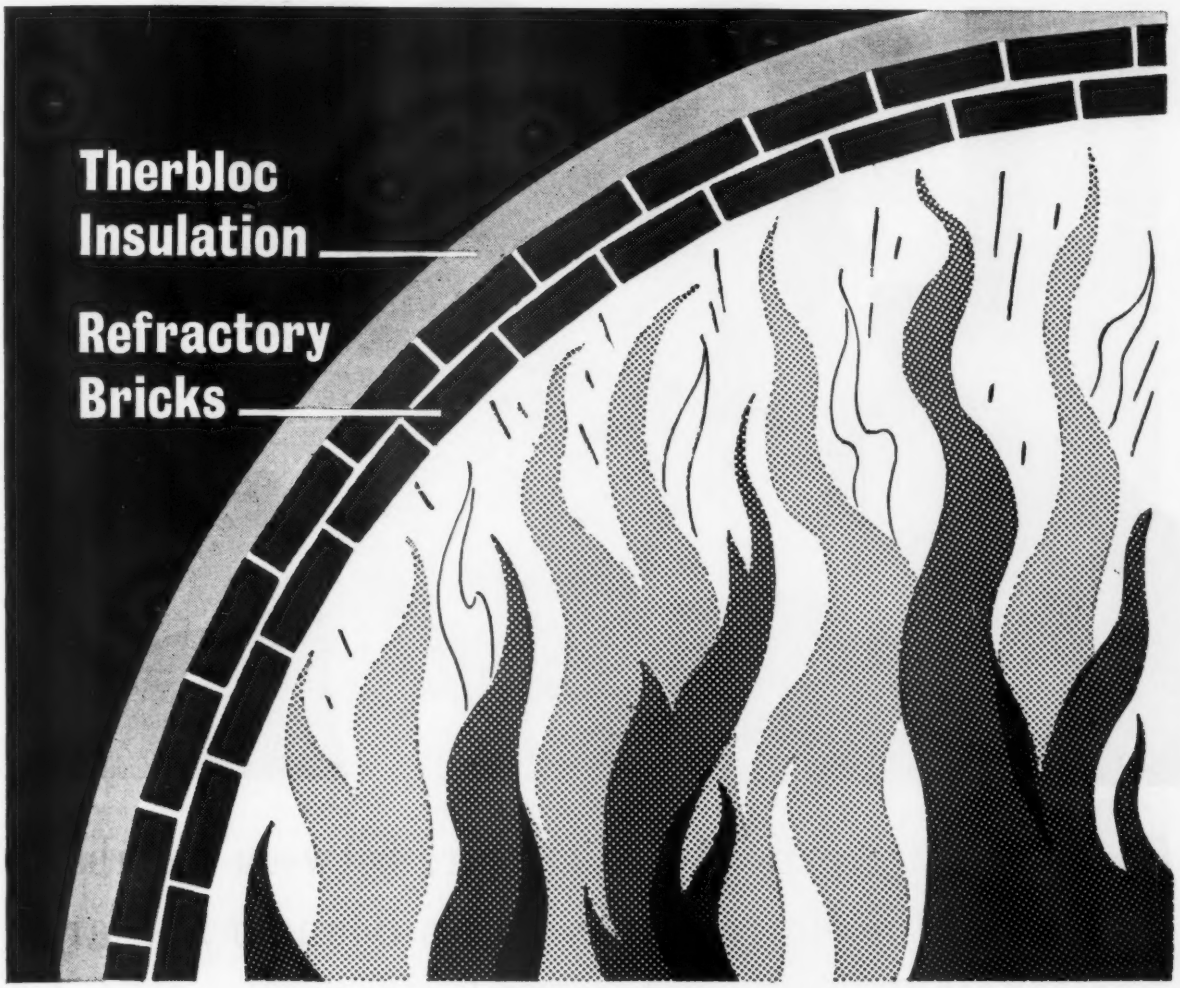

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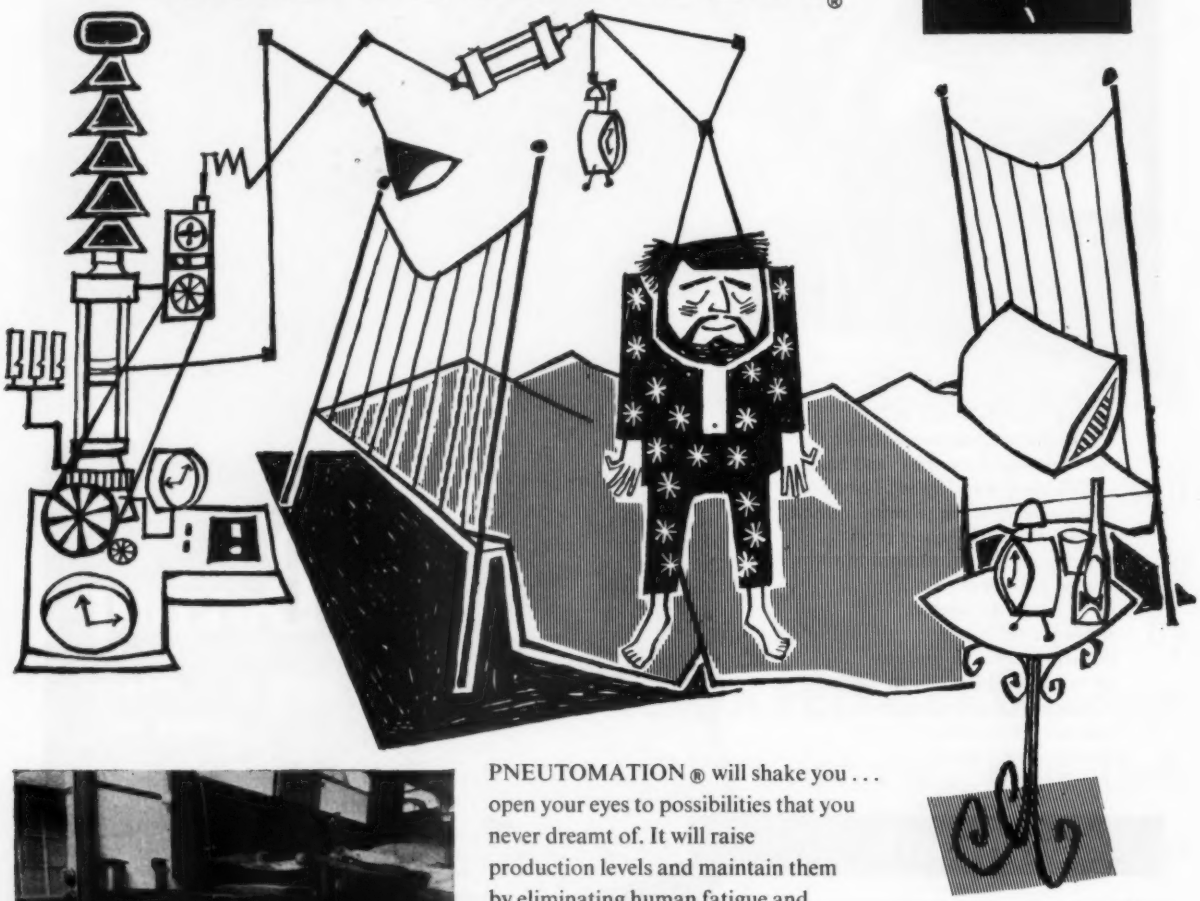

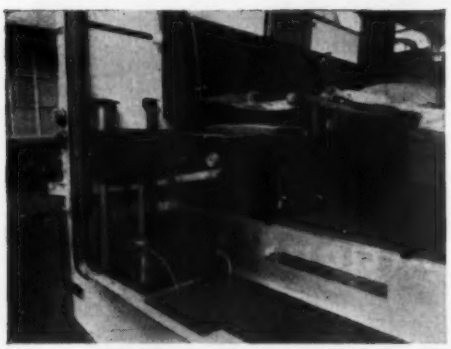

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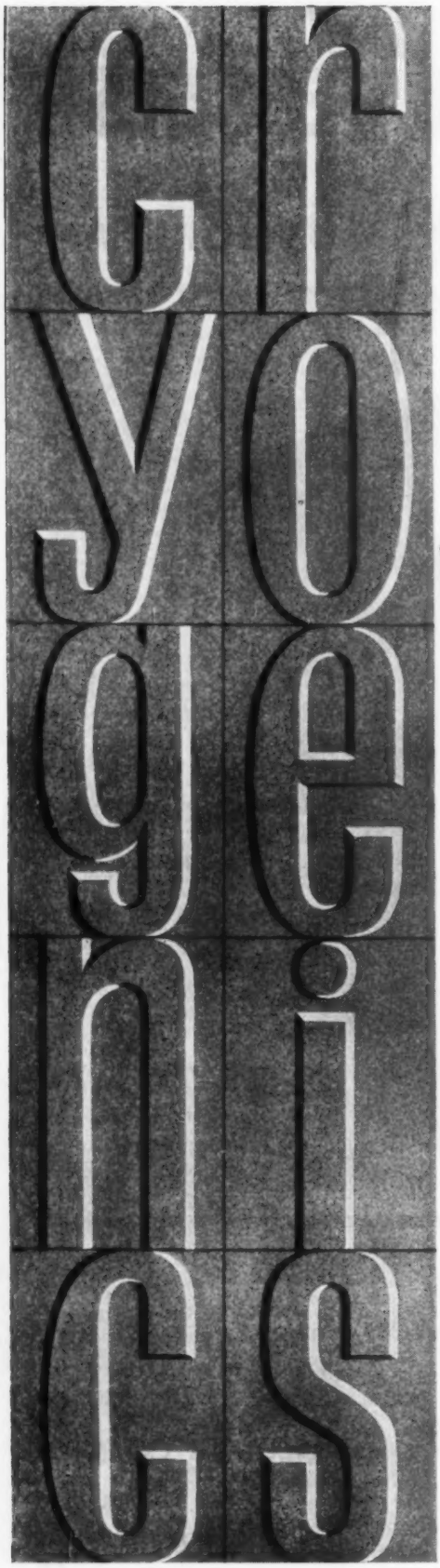

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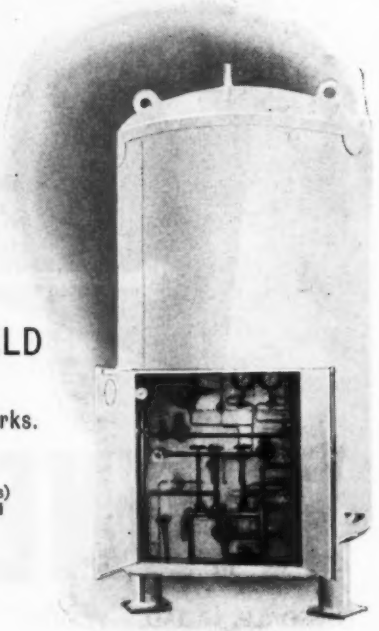

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Polonium-210 and radium-226 are frequently used as the basis of neutron sources for commissioning nuclear reactors, but another alpha emitter now becoming available for this purpose is thorium-228. For example, this is being used for the Central Electricity Generating Board's power reactors at Bradwell and Berkeley.

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POLONIUM-210	**2.5×10^6**	**138.4 days**
RADIUM-226	**1.3×10^7**	**1620 years**
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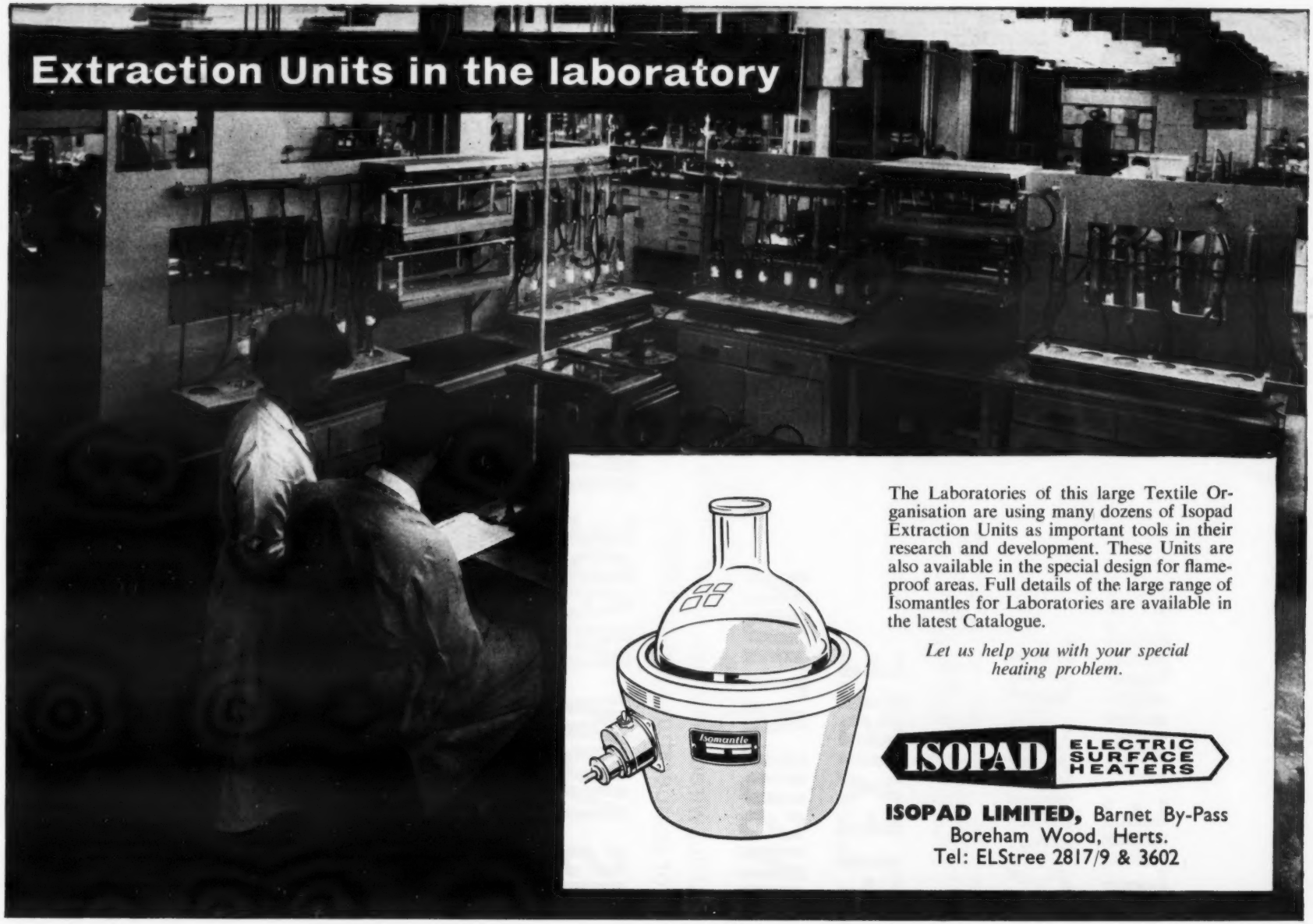

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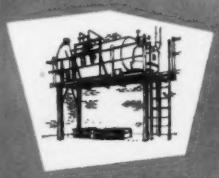
Installation's no problem. You need no special foundations, no plinths, no bolting down—just a flat floor that will bear 6 cwt./sq. ft. —the I.C.I. tank is supplied as a self-contained unit complete with chassis and, if necessary, can be easily moved.



If ground-space is scarce, the tank can be sited up to 20 ft. above floor-level.

Easy to operate — CO_2 is available at the opening of a valve, and the tank can be refilled without interrupting supply.

Easy to maintain and service — all parts readily accessible; for instance, the contents gauge can be serviced without emptying the tank.

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DK.336

Even if you buy as little as 30 tons of CO_2 a year, the cheapest way of buying it is in bulk—and the best storage container is I.C.I.'s 5-ton liquid CO_2 tank. You'll need only 6 or 7 deliveries a year, and the tank will pay for itself in a very short time.

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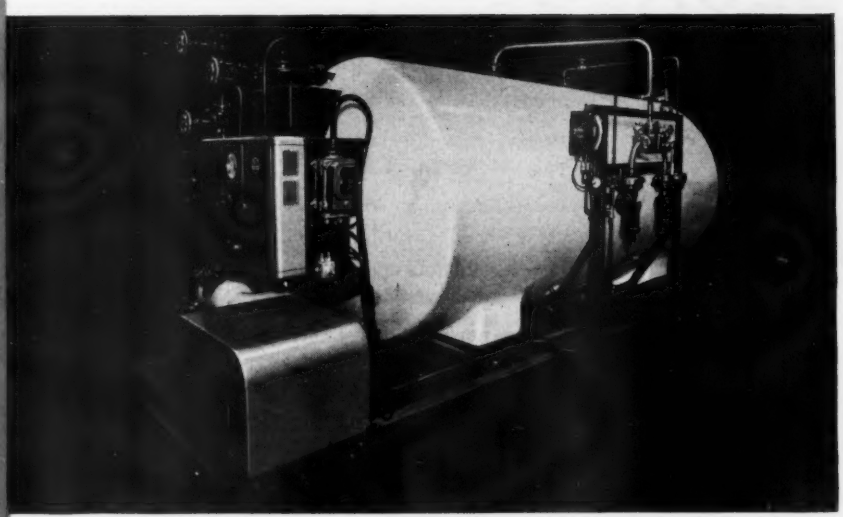
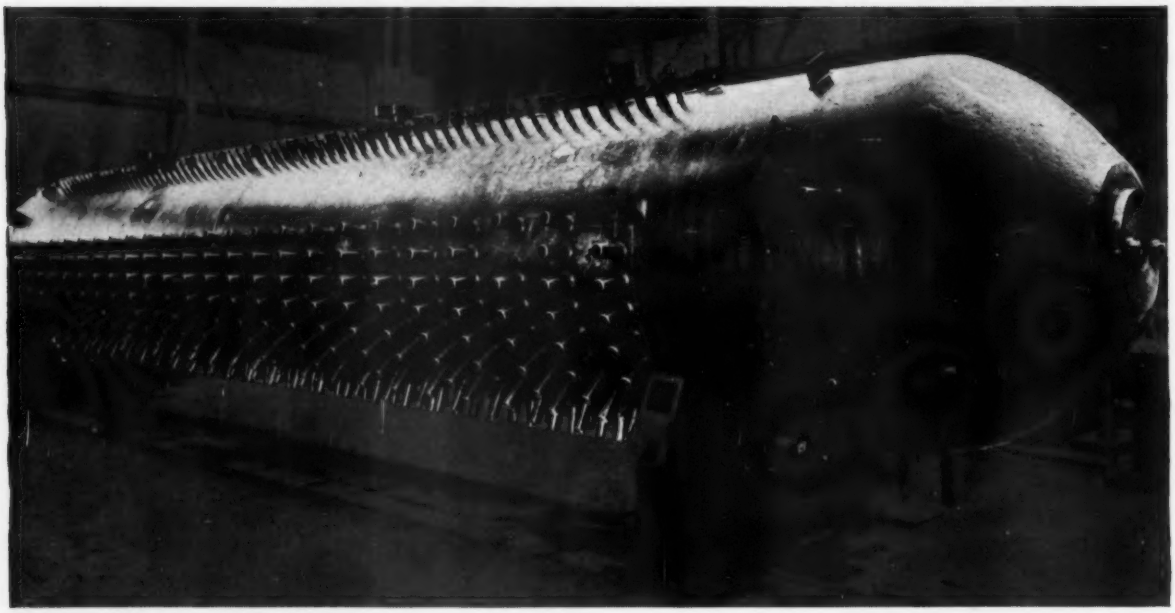
You'll find that for you, as for many other users, the I.C.I. liquid CO_2 tank will mean extra profit.

I.C.I.'s LIQUID CO_2 TANK MEANS TONS OF ECONOMY



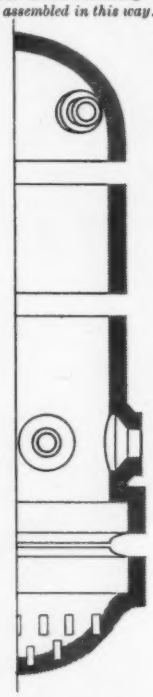
If you'd like to discuss the economics of bulk delivery, or the installation of I.C.I.'s tank at your works—or if you'd simply like to read I.C.I.'s booklet on liquid CO_2 in bulk, get in touch with Imperial Chemical Industries Ltd., London, S.W.1.

WHY »REISHOLZ« REACTOR VESSELS TUBES AND NUCLEAR COMPONENTS?



BECAUSE

This 60 ton high-pressure vessel is an example of the REISHOLZ *technique of assembling exceptionally large units from several sections without longitudinal welds. Below: Exploded view of reactor vessel assembled in this way.*



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Because REISHOLZ operate a unique horizontal press producing very large seamless vessels and tubes up to 35 in. i.d. and 9 in. wall thickness

Because REISHOLZ special welding facilities (including build-up welding) enable them to assemble up to 60 ft. long pressure vessels without longitudinal welds, for any desired pressure

Because REISHOLZ research into the suitability of various steels for nuclear engineering have given them a wealth of unrivalled know-how in this specialized field

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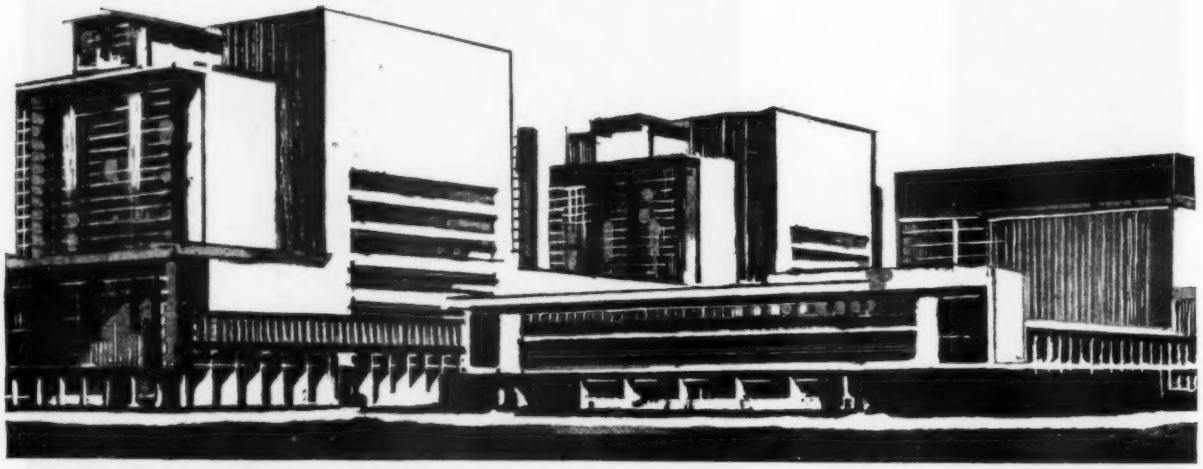

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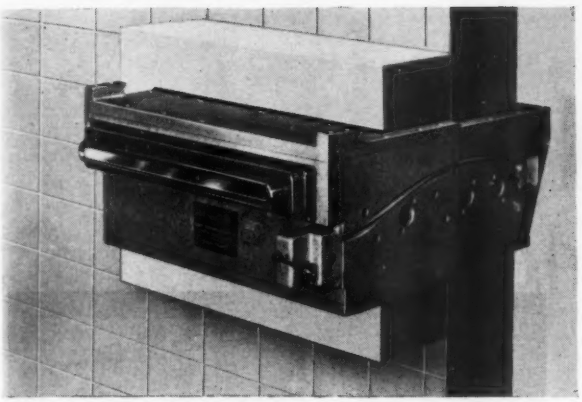

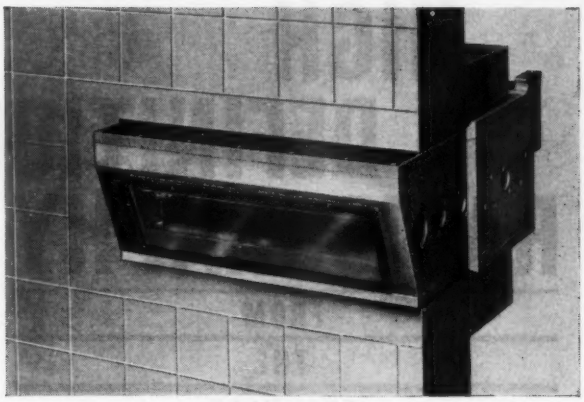

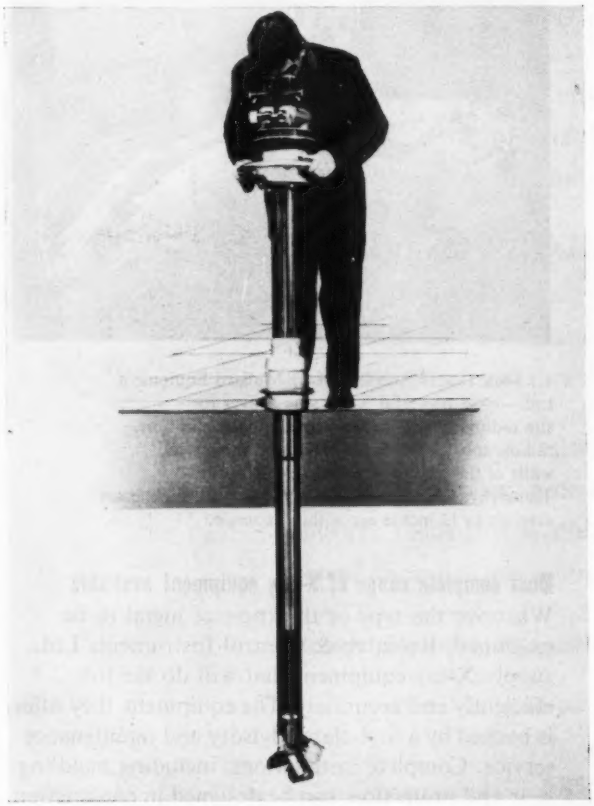

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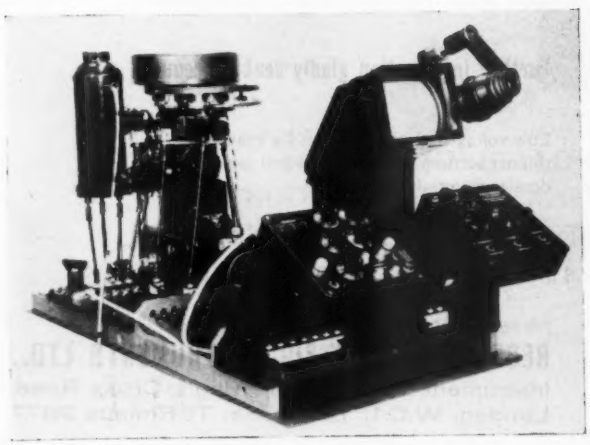

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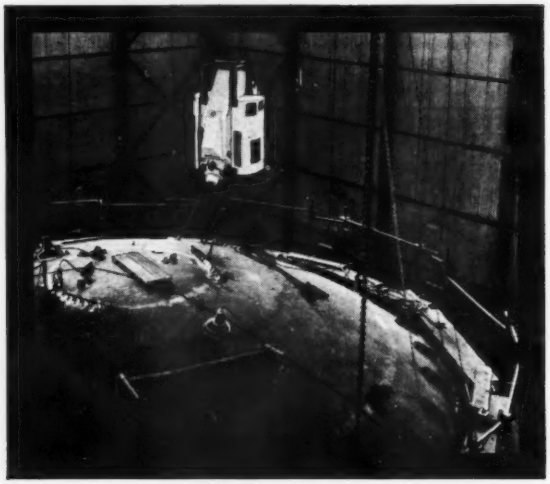

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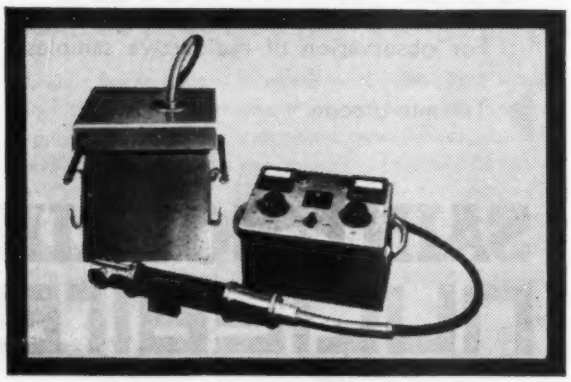

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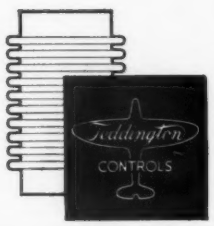

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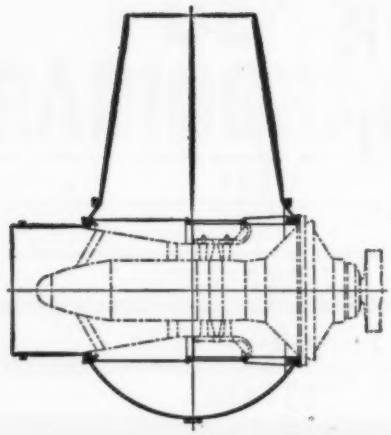
New thinking for Trawsfynydd



CO_2 CIRCULATORS

As every engineer knows, the thickness of plate required to contain a given pressure is halved if the vessel is spherical instead of cylindrical. It is odd—but nevertheless true—that it was not until our own engineers were confronted with the design of the CO_2 circulatory system for Trawsfynydd that the elementary principle was put into practice on large pressure pipework.
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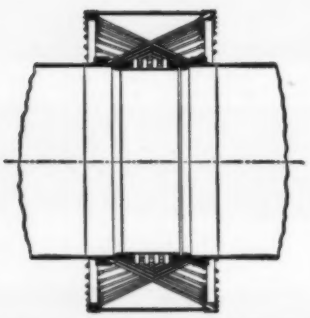

EXPANSION JOINTS

It is standard practice to take up the expansion of large diameter pipework by flexing at what are essentially hinged joints. These of course have to provide restraint against axial forces—over 1,000,000 lb. in the Trawsfynydd ducting. The usual solutions, an internal metal tongue or a hinged joint are heavy, cumbersome and, moreover, flexible in one direction only. The hinge we have devised is flexible in *all* directions, by elastic straining of the high-tensile steel, restraining rods. The circumferential pressure is taken by a metal bellows, faired internally by a floating sleeve.

These ideas are not our only contribution to Trawsfynydd. As well as the complete CO_2 circulation system, we are building the whole of the generating plant, comprising steam turbo-alternators, condensing plant and feed heating systems.

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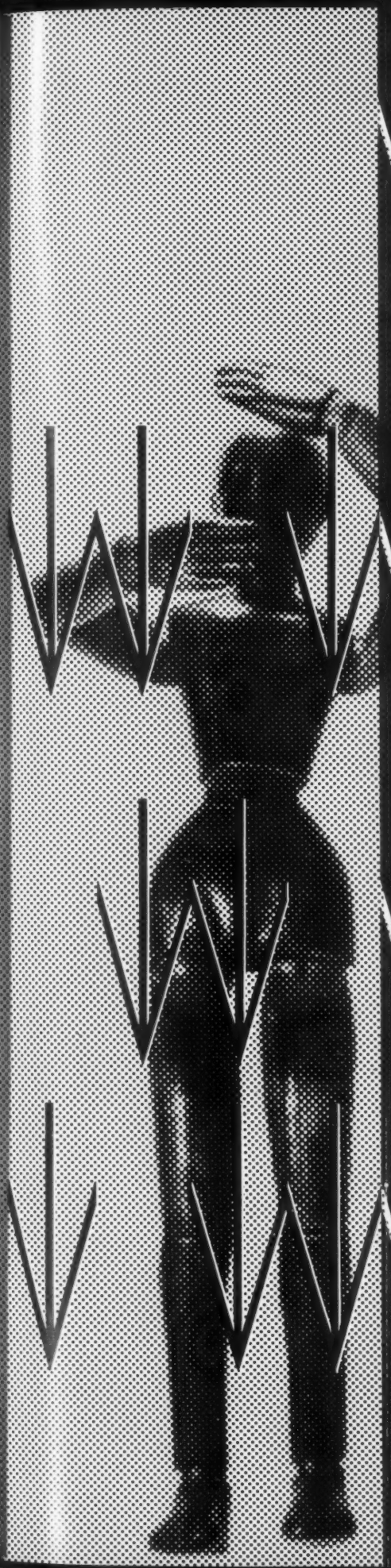

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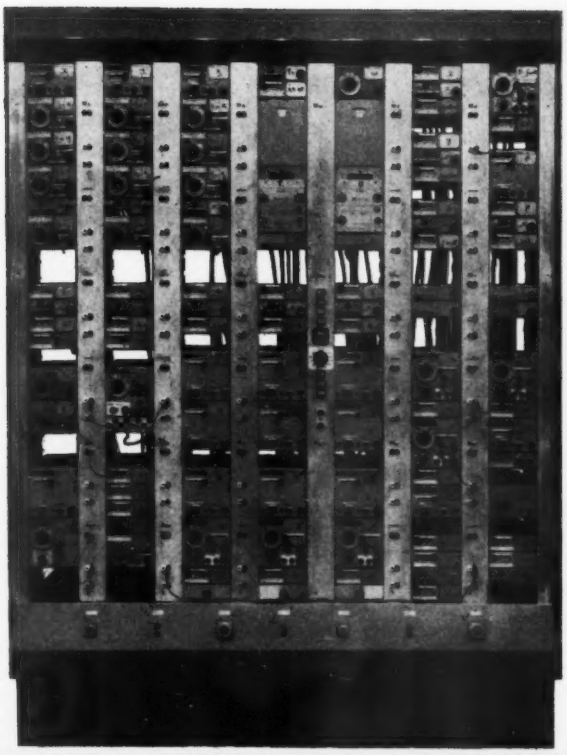

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Thermo-dynamics
Operational research

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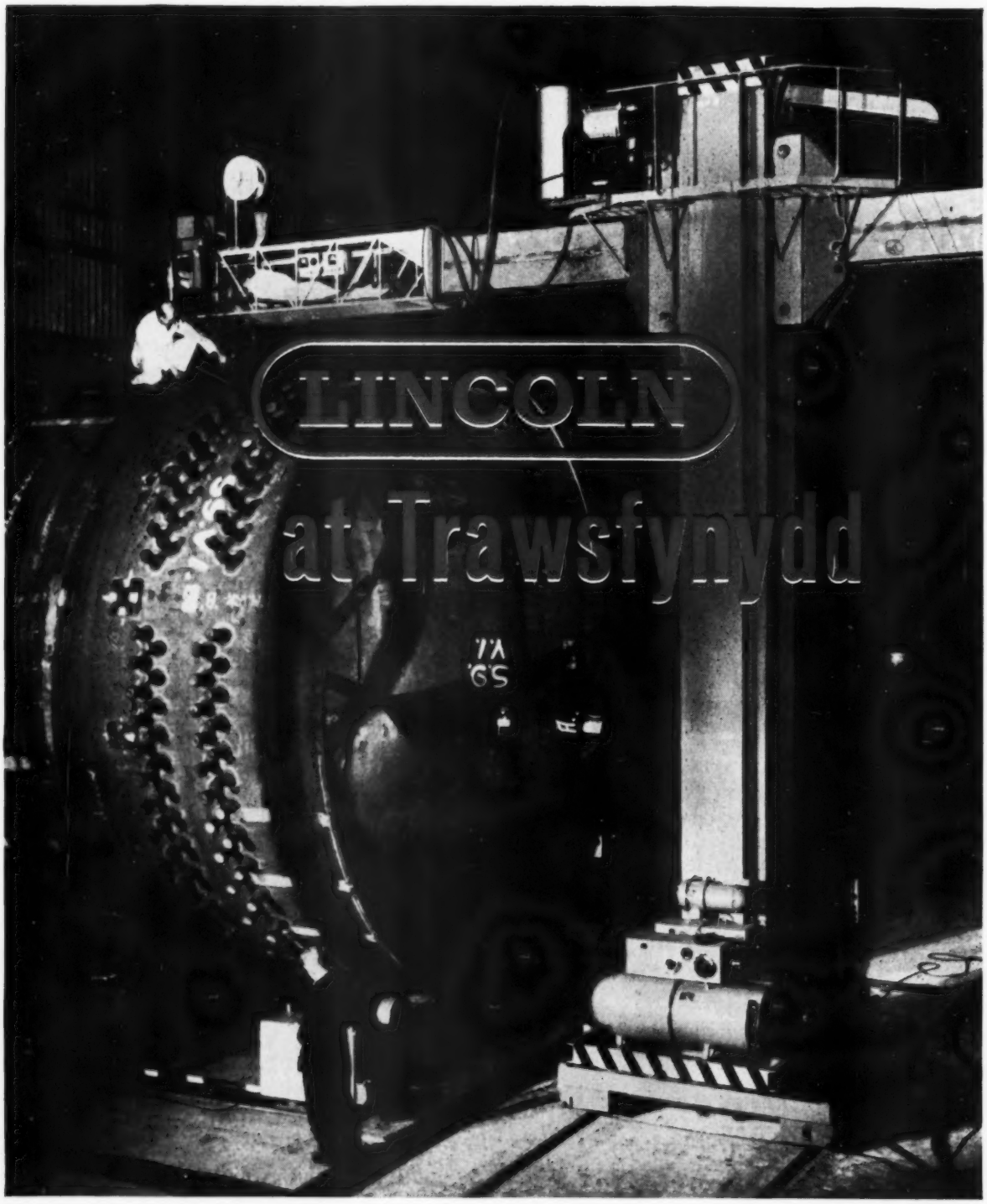

All the twelve 350 ton Heat Exchangers being built for Atomic Power Constructions Ltd. by International Combustion Co. Ltd. at Trawsfynydd Nuclear Power Station, North Wales, are being weld-assembled with Lincolnweld Fully Automatic Welding Units exclusively using Lincoln Wire and Flux. Lincolnweld equipment has also been employed by Babcock & Wilcox Ltd. for the welding of the two 61 ft. diameter, 3½" thick spheres which will house the Nuclear Reactors.

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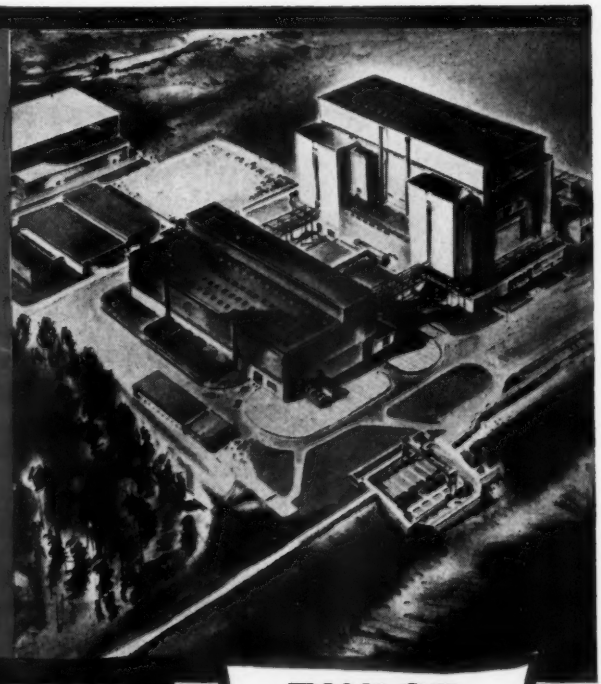

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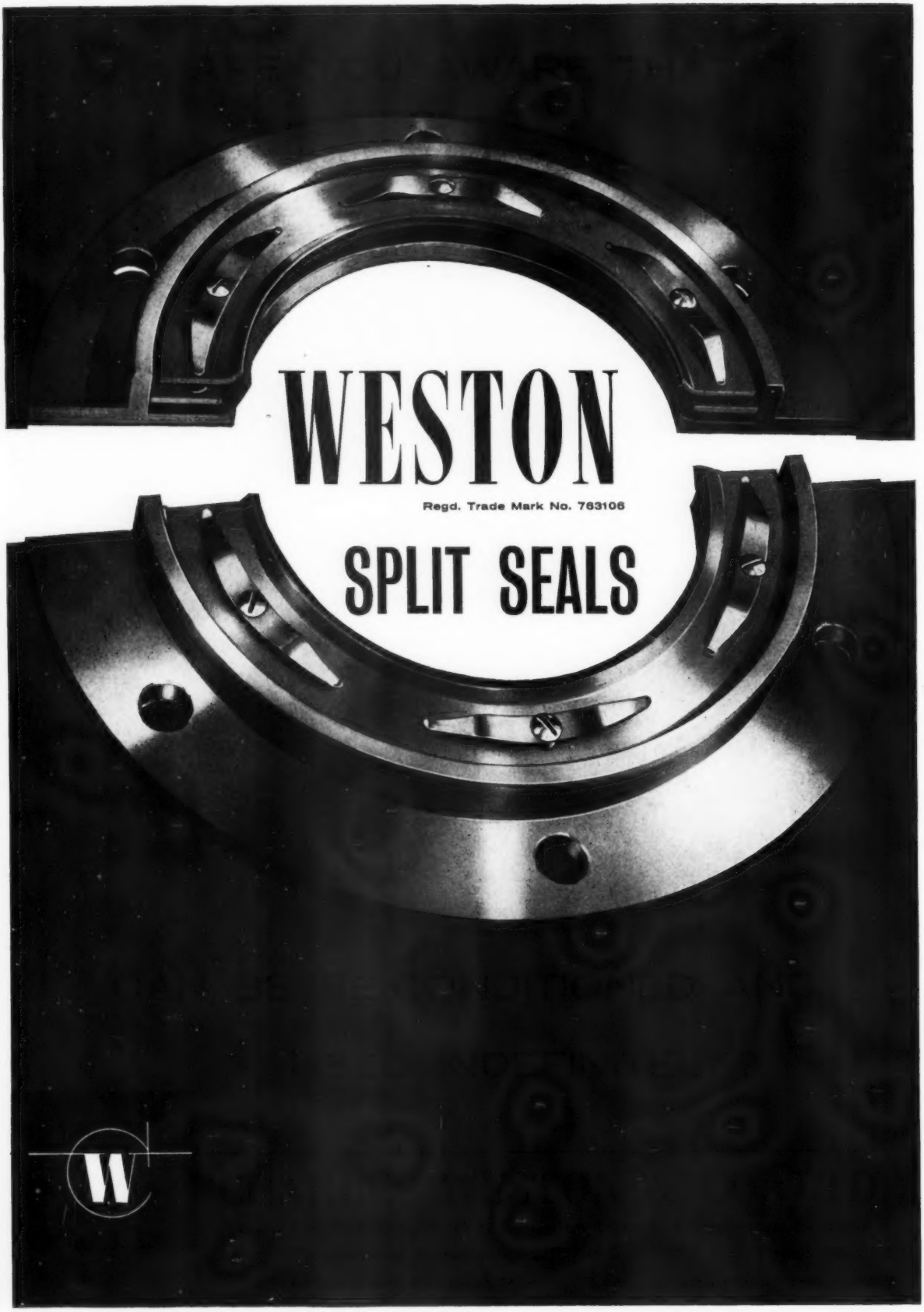

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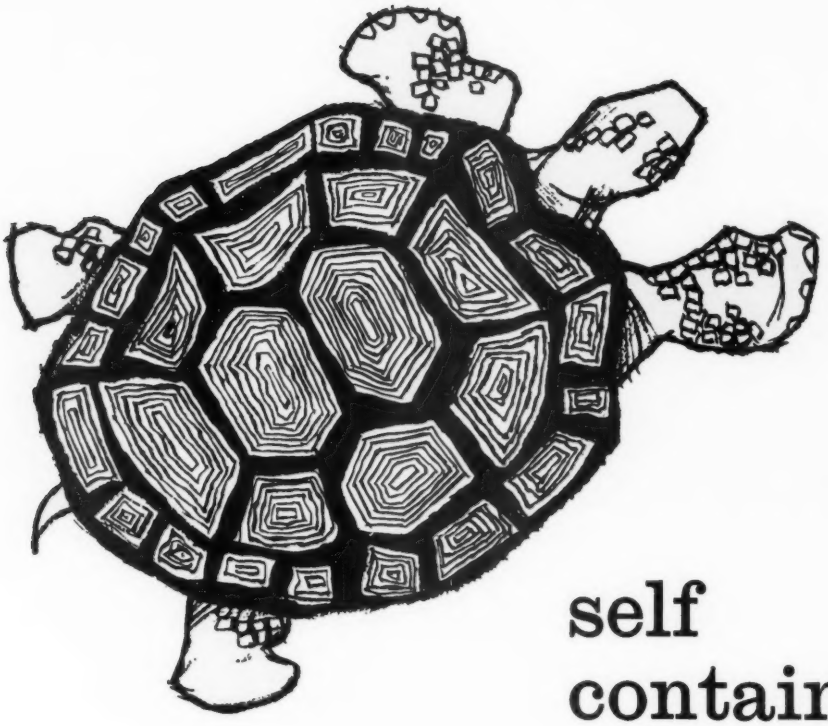

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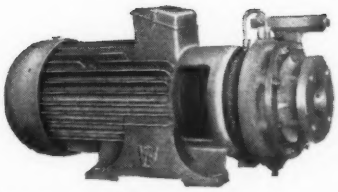

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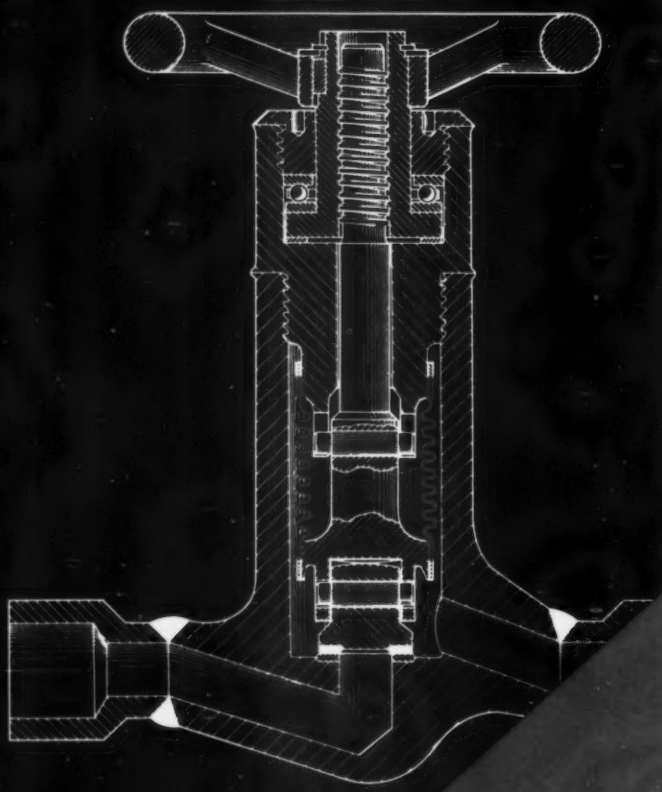

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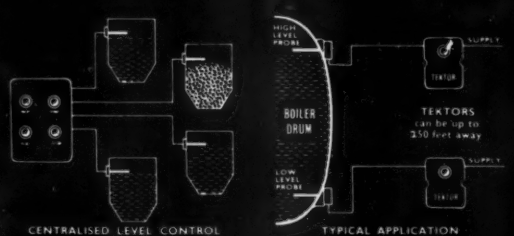

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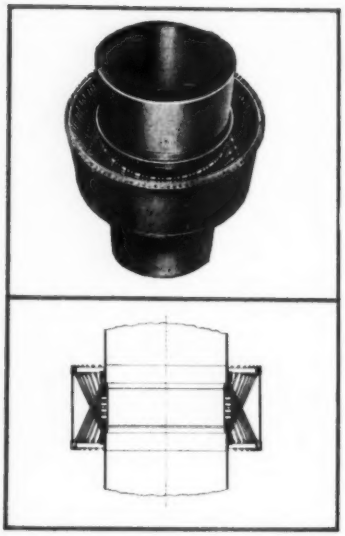
(*c*) They had to have a surface completely free from machining marks.

These bars, after extensive experiments and tests, have been produced and incorporated in the mechanism. In use, they show "extremely high fatigue strength in the high deflection range".



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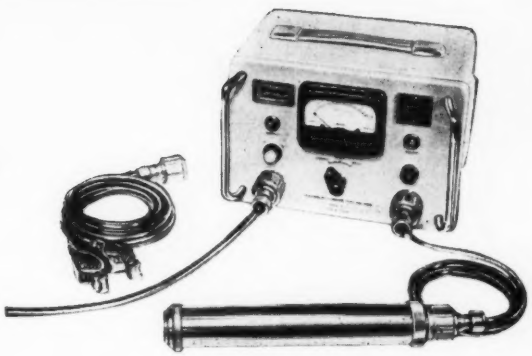
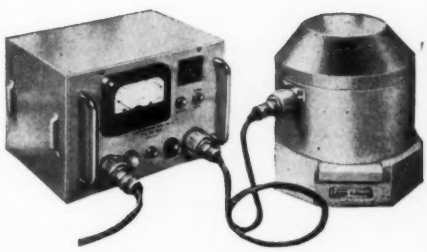


Selective Gamma Monitor type 1080
—Publication No. PNL 111

PNL programmes for nucleonic development

PNL is engaged in the design and manufacture of standard and specialised nuclear instrumentation—burst fuel element detectors for reactors, flux scanning equipment, radiation detectors of all types, process control instrumentation, health and defence instruments.

The parallel production by PNL of so much that is complementary in nuclear instrumentation has established within the Company a unique bank of scientific skills and techniques, which is now offered for the development of new projects. The Company's liaison engineers are freely available to assist with problems in their field.



General Purpose Contamination Monitor type 1065
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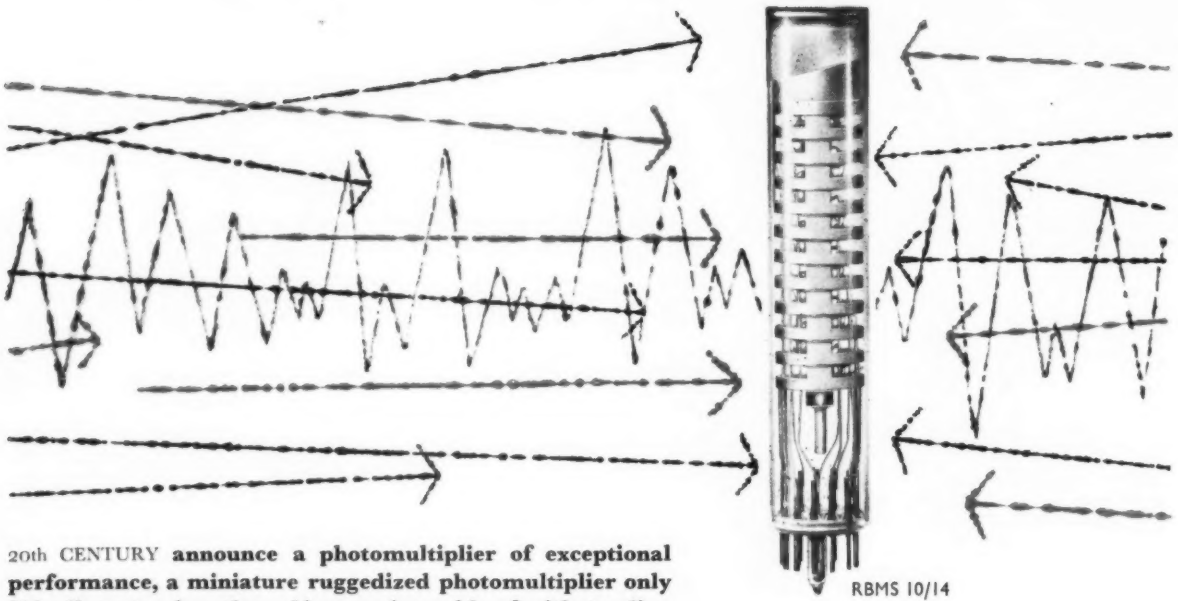

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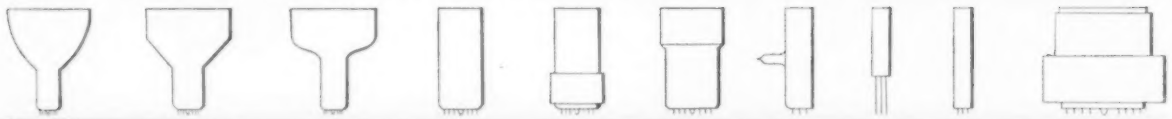

CHWR/20C/361

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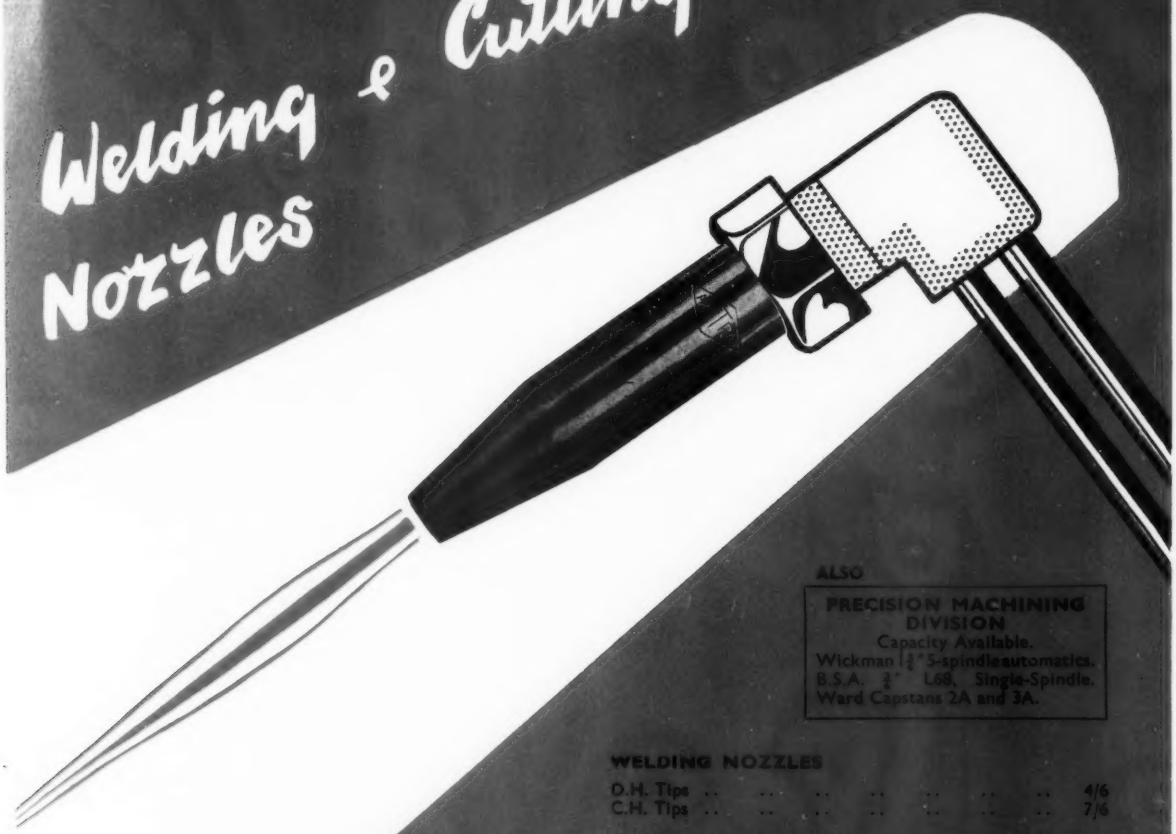

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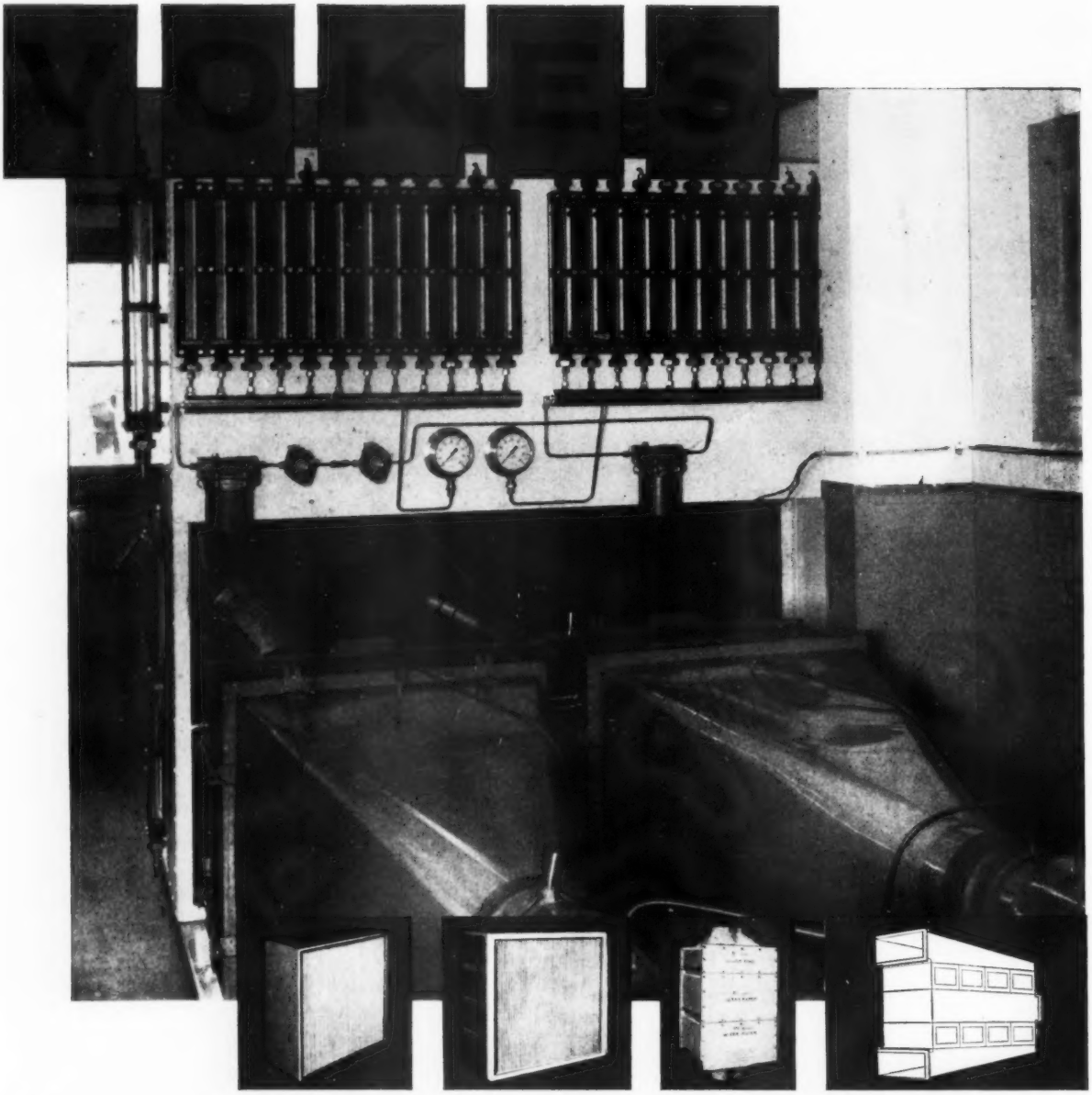

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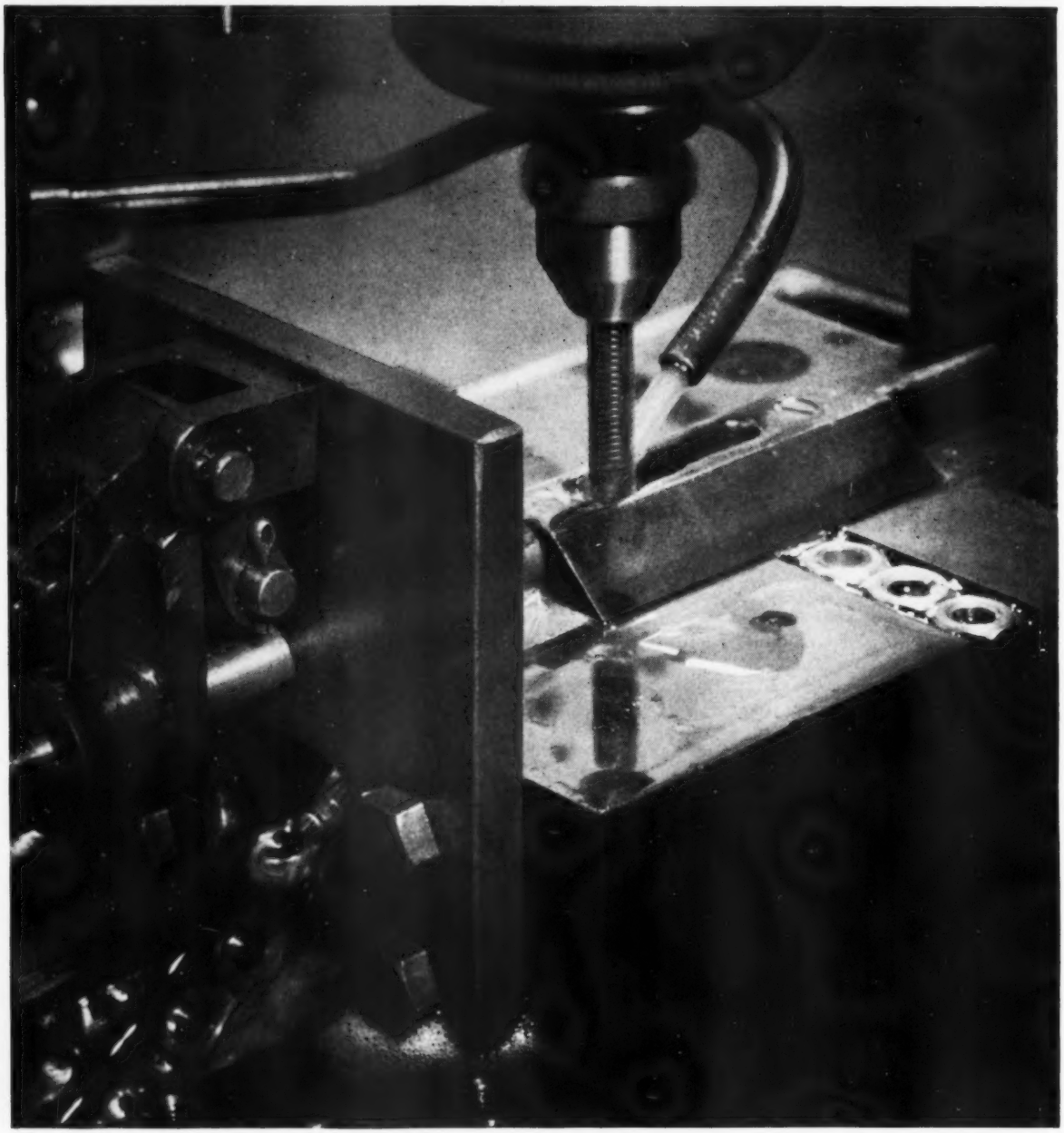
Shell achievement



A famous aero-engine firm found it could drastically reduce the cost of producing nuts made from S.62 steel, by changing over from conventional cutting oils to Shell Garia Oil 115. The facts are these. S.62 steel is heat-resistant and stainless. The quality of this steel and the call for very fine tolerances, as well as a very high percentage of full depth of thread, presented costly manufacturing problems. The breakage of taps, the need for constant re-setting, and the high proportion of rejects, built up the average cost of the nuts to over 1/2d. each.

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SHELL

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Nuclear Power OCTOBER 1961 VOLUME 6 NUMBER 66

VIEWPOINTS letters to the Editor

Standardize fuel elements

SIR: In your September issue you mentioned (page 53) that the Hunterston fuel element design is to be modified so that the fins will be helical instead of straight. In other words, the design will be brought into line with all the other industrial power station elements. The reason for the change is stated to be production costs. I have often wondered whether the minor differences which exist between the fuel elements now waiting to go into production are really justified.

Our impressive nuclear programme is made up of ten different designs of reactor (including Calder), and ten different designs of fuel elements are apparently required for them. It is possible that Britain will maintain a steady programme of construction of similar reactors for some years yet. Is it practicable or reasonable to limit the freedom of the manufacturers by asking them to design future reactors round one of the existing fuel elements? The answer must be based on knowledge of much technical, financial and commercial data which is available only to very few people. However, I suggest that on the evidence of published information the present diversity is not justified.

Basic Similarity

When fuel elements at Calder started bowing, designers began to think seriously about methods of supporting each fuel element individually in the large power reactors where the fuel is subjected to much higher irradiation. The result of their efforts is embodied in the design of Berkeley (element hung from a frame of graphite and zirconium) and Hunterston (element supported in a graphite cylinder by zirconium beams). Nevertheless, Bradwell, designed at the same period, rejected individual supports and proposed stacking on the Calder principle. The Calder braces, however, were replaced by full length additional fins or splitters which also served the function of barriers encouraging turbulence of the gas.

The significant point, however, is that since 1957 every fuel element except one has been basically the same as for Bradwell—a uranium rod about 1 in dia. clad in a magnesium alloy jacket bearing a finned surface known as a polyzonal multistart helical thread. (The exception is the hollow element chosen by the Japanese.) Since the CEGB approved the Bradwell element, which was obviously simpler and cheaper than any individually supported design could be, all subsequent designs have followed the same pattern. Hunterston elements were at one time finned differently, but are now apparently to be the same as the rest. Why, then, not make them all completely identical?

Fuel element design is an inherent part of core design. It is quite certain that if the wrong fuel elements were delivered to one of the reactors recently completed—supposing, for example, the uranium diameter was 1·10 in instead of 1·15 in—then the careful optimization work would be destroyed and the efficiency or output of the reactor would be reduced. But supposing a designer is told *before* he carries out his optimization to use a 1·10 in dia. rod, would his design really be seriously handicapped? Might not the same argument apply to rod length and number in a channel?

The strongest argument that could be produced against standardizing on fin design would be to show that the extended surface of the element requires to be specially designed for the reactor in which it works. This is not an easy subject for anyone but the dedicated specialist to comment upon. From the Symposium on the subject last year I gained the impression that finned cans are designed by trial and error rather than by mathematical theory; or to be more exact, by intelligent exploitation of experimental results.

The empiricism of the methods used is well explained in the paper by Gott and Bond which opened the Symposium. They included a diagram showing the increase in channel rating which has taken place between Bepo and the latest CEGB stations. Windscale temperatures were far higher than Bepo, and Calder far higher than Windscale; but the rate of development then slows rapidly, so that the increase between the first and the seventh CEGB design is shown to be very small. The authors themselves say 'It is not suggested, however, that the increases in rating which remain to be obtained with the uranium metal-magnox fuel element are very large'. From the evidence, therefore, it seems reasonable to conclude that no further 'break through' in fin design is likely, and that present designs are very near to maximum efficiency.

Mass Production

The other side of the argument is to enquire whether there is anything to be gained from standardizing a fuel element, from the point of view of the fuel manufacturer, who would presumably pass on any cost savings to the purchaser. Springfields is now committed to the production of nine or ten different designs of fuel elements. At this moment three of these are in production. The nuclear station containing two average reactors demands 20,000 elements per year, or 180 tons of uranium worth about £3·2 million.

Looking at this purely as a problem of production engineering, we have this question. If we tool up to produce 20,000 articles a year, each worth £160, then by how much can we reduce the cost of each if we double the throughput, rather than re-equip the production line to produce an equal number of a different, though similar articles? Suppose the saving is 5%. (No justification whatever is offered for this figure, but is it unreasonable?) The saving in fuel cost for this station will then be: 5% of £3·2 million = £160,000. Now this saving will be made annually for the planned life of the station. If a tenderer can offer a station which will use this 'cheaper' fuel (cheaper because it is already in production) then his tender has a price advantage equal to the capitalized value of the annual fuel saving. This value is nearly £2 million using the above assumptions or about £4/kW installed.

It seems probable that the CEGB could now specify a 'standard' fuel element when calling for tenders, and they could quote the fuel cost saving which they would assume when making their tender cost evaluation. Can anything be done to standardize the fuel elements for the designs already accepted? Unfortunately, this does not seem to be practicable. As soon as a manufacturer receives a letter of intent from the purchaser, he immediately places orders for material on which delivery times are important. Surprisingly quickly, irrevocable steps are taken which freeze the main outline of the design. As soon as steel of a certain type and thickness is ordered, the gas pressure is fixed, ordering parts of the gas circulators designed for a certain gas flow and horsepower may fix the core pressure drop and channel resistance; even the length of the fuel element may be frozen when the charge machine pressure vessel is ordered. Cancellations and disruption of a tight programme could very quickly lose more than the potential savings.

R. F. GUARD

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OPINION

A new pattern for research ?

A FEAR OF GROWING international competition, emphasized by the implications associated with Common Market membership, is prevalent in some quarters. A look at the present pattern of nuclear research and development in this country is therefore desirable to see if it is both sufficiently adequate and properly deployed to cope with the future.

The current budget for the UK Atomic Energy Authority is £78 million, and in all, since 1955, the total official investment in nuclear development is over £500 million, large in relationship to other UK expenditure but small compared with that in America. The amount is not excessive if one considers the nature of the challenge presented to the Authority and the number of establishments that have had to be set up to tackle the tremendous tasks involved, staffed by nearly 41,000 people over 12 per cent of whom are qualified scientists and engineers. Of this expenditure, a high, though unknown, proportion is devoted to industrial applications of atomic energy.

The Generating Board's investment in research and development, on the other hand, is less impressive. The estimated annual amount for nuclear and conventional research is just over £2 million, representing only 0·5 per cent of its total income. Is this sufficient? According to an estimate made in 1958 by the Council for Scientific and Industrial Research, the amount spent by the manufacturing industry as a whole on research and development was just over 4 per cent of its contribution to the gross national product. Admittedly, the CEGB'S expenditure is double that of two years ago but it has to cover all aspects of generation, not only nuclear, which makes it seem a drop in the ocean if account is taken of the vast undertakings to which the Board is committed. The Herbert Committee in 1956 criticized the then low CEGB research expenditure of less than 0·2 per cent and the heavy reliance of the Board on the research efforts by outside organizations. The present figure is not really much of a step forward. That the other nationalized industries fare even worse seems to suggest there are influences beyond the authorities' control preventing logical expansion of necessary effort—the Treasury in fact.

The UKAEA by necessity is and always has been the predominant body in nuclear developments even to the extent of overseeing the commissioning the CEGB's own nuclear power stations, a feature of some irritation to the contractors and the Board's own engineers on the site. With the opening up of the CEGB's £2 million Berkeley Nuclear Laboratories and the building up of the nuclear team at the headquarter's Research and Development Department a new pattern of relationship could well evolve, with the CEGB taking on more and more responsibility not only for its own nuclear plant but also for advising on future advanced systems of likely application to the electricity supply industry. Whatever happens in the future, close co-ordination between the Board and the AEA's Reactor Group, with less personal or power 'politics', is vital, to cut wastage in research effort and manpower. No doubt the CEGB would also like its own research and test reactor—and there is a good case for this —but there seems little prospect of Treasury approval, at least in the immediate future.

What of the part played by industry? Does this make a reasonable fit in the nuclear research pattern? The main research and development work of the consortia, at Knutsford, Whestone, Erith and Heston, relates directly to the power stations for which they have contracts. Other than this very little effort is being made in research on more advanced designs ; almost the only work being done is that which comes from the AEA in the form of R & D contracts. Individually this is small, anyway, (the total figure for 1959/60 was only £3.6 million and this included work carried out by the universities).

It may be argued that industry in this country, in general, is reluctant to spend its own money in long term research and that this is a contributory factor to the increasing struggle that we are having in facing foreign competition. If the Authority is to remain the predominant sponsor of forward thinking and development then one major grievance prevalent in industry should be carefully examined. It is the way in which work has been doled out in 'penny numbers'. Where whole reactor concepts are in question, the French pattern of research and developmen deserves consideration. Here industrial concerns are called in at the first stage, acting in a consultative role. As the project develops their services are used increasingly and are paid for. This to us sounds reasonable ; the considerable experience built up by engineering firms against a background of making a business pay should not be ignored. Too great a bureaucratic attitude can be costly to a nation facing financial embarrassment. Admittedly, the present system of Nuclear Power Consultative Committees brings industry into the picture but at their expense and with dubious gain.

Another idea with considerable promise and one that has been proposed by Pye, is the collaboration by private firms in running their own research reactor, possibly through an independent Institute for Nuclear Research. Is it not surprising that in a country so advanced in nuclear energy as the UK there is only one private reactor, that of the AEI, and none at any of the universities? The facilities available at Harwell and Winfrith are very much committed to Authority experiments leaving little or no time for private effort. The number of firms who could use to advantage such an experimental facility are growing ; the setting up of such a collaborative scheme therefore in the near future seems necessary.

EVANS OF PORTSMOUTH

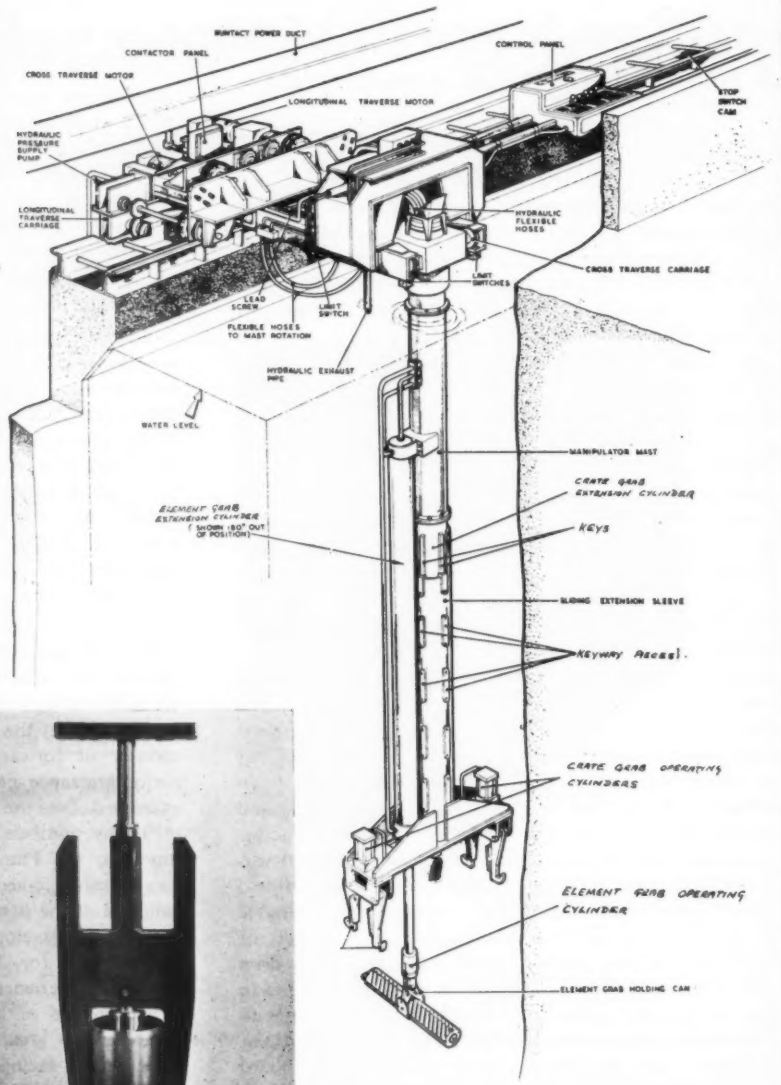
ARE PROUD OF THEIR PART

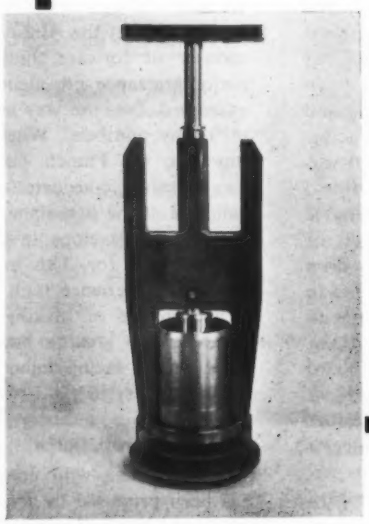
IN THE

Berkeley

STORY

EVANS were responsible for the design, manufacture and installation of the Crate Extraction and Fuel Element Manipulators and the fully automatic Fuel Element Destrutting and Definning Machines in collaboration with the Nuclear Power Group.





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WORLDVIEW

the month in atomic energy

EUROPE

AEA reaches agreement on Latina fuel

London A factor delaying the announcement of the Latina fuel interim agreement between the AEA and SIMEA is believed to have been the need on the Italian side to settle the problem of special aid for European Community nuclear power plants with Euratom. This has now been resolved for the AEA announced on September 13 that 'a preliminary agreement has been concluded for the supply of the first 400 tonnes of fuel . . .' (for the 200 MW Latina station).

The fuel charge for the first loading is approximately 270 tonnes and the AEA say this initial charge will 'be ready by the time the reactor is ready for loading'. This should be early in 1962.

Latina is being built by the Nuclear Power Plant Co. (The Nuclear Power Group) for SIMEA (Societa Italiana Meridionale Energia Atomica).

The question of special aid comes from the Euratom decision in July (see *Worldview*, June, p 53, August, p 54) to help reactor projects in the Community by a subsidy for fuel element manufacture, other plant component costs and the difference between nuclear and conventional power costs for the early years of operation. Fuel assistance is conditional on manufacturing the reactor fuel within the Community.

This stipulation makes it unlikely that SIMEA will receive any subsidy for the 400 tonnes of fuel which should cost in the region of £10-14,000 per tonne if Dungeness estimates are any guide. Special arrangements will no doubt have to be made for the transport of fuel and these may have an upward effect on the price. So far, the AEA is not prepared to release any details on price for the Latina fuel.

Negotiations on the supply of the Latina fuel have been continuing erratically for some time and the present agreement is believed to be based on a draft letter of intent drawn up in 1958. Early this year, a tentative step was taken to ask for tenders for Latina fuel but no results were announced. However, it is known that while the AEA price was not the lowest, no other offers could match the Authority's guarantees or buy-back price.

Swedish progress in plasma experiment

Stockholm A Swedish research team has succeeded in keeping together ionized heavy hydrogen gas, through which a high current was being passed, for as long as seven-thousandths of a second. The plasma had been stabilized by rotating it at a high speed, Dr Bo Lehnert, leader of the team at the Royal Technical College, Stockholm, announced.

Dr Lehnert claimed that the containment was a time record and that temperatures ranging from two to three million degrees centigrade had been reached. He believed the problems of confining a hot gas and of the instability of the magnetic field were near solution and that by modifying their apparatus, the plasma could be held together for longer periods.

The complete experiment was reported at the IAEA Conference on Plasma Physics and Controlled Nuclear Fusion Research held in Salzburg recently. It was here that Mr Sterling Cole, the Agency's Director General told 508 scientists from 29 countries that great strides had taken place in the years since the 1958 Geneva conference. The meeting was also told that it would be desirable to have another conference in 1964.†

A further conference, the Fifth on Ionization Phenomena, was held at Munich and attracted some 1000 scientists.

†*Proceedings of the Salzburg Conference will be published in three special issues of the IAEA journal* 'Nuclear Fusion'. *The first issue will appear in December, 1961, or earlier if possible.*

• **Hinkley Point progress** The heavy civil engineering works are complete at the 500 MW Hinkley Point nuclear power station. The first reactor is due to start fuel loading next March; clean conditions have been established in No. 1 reactor pressure vessel and graphite core erection is about to begin.

• **AEA man joins industry** J. D. Glanville, at present Commercial Director with the UKAEA at Risley, joins Richardsons Westgarth & Co. Ltd as Group Production Director at the beginning of October, 1961. Last month it was announced that P. T. Fletcher, special advisor to the AEA Member for Reactors, would join the United Power Company on October 1 as a director.

• **Another Polish reactor** The USSR is to help Poland build her second research reactor at Crakow. This was announced after the recent signing of the protocol to the Soviet-Polish agreement on mutual help and co-operation in nuclear energy. It was then said the Swierk (Warsaw) reactor facilities could no longer meet research demands.

• **East German power corporation** The first East German nuclear power station is to be run by a recently established public corporation, the Volkseigene Betrieb Atomkraftwerk 1.

• **Radioactivity in water** Radioactivity concentration in British drinking water is far below the maximum permissible level says a report '*Radiostrontium and Radiocaesium in Drinking Water in the United Kingdom, Results to* 1960' (Stationery Office, 3s). Another report was also issued at the same time '*The Fate of Radioactive Effluent Discharged from the AERE, Harwell, into the River Thames*' (Stationery Office, 4s).

POWER LINK The North Crossing Tower of the 400,000 volt overhead power link across the Thames between Essex and Kent with a set of suspension insulators in course of erection. The line will join up with the cross-Channel link and Dungeness nuclear power station

WORLDVIEW

Russians may design 800 MW fast reactor

Vienna Soviet scientists are thinking of designing a fast reactor of 800 MW or more, according to Dr Ivan Bondarenko of the USSR. He was speaking in Vienna at the recent IAEA seminar on the Physics of Fast and Intermediate Reactors. Plans in the United Kingdom, France and the United States were also outlined at the meeting.

The Soviet fast reactor programme, which started in 1948, might be divided into a theoretical and a practical stage, stated Dr Bondarenko. The transition to the practical stage began with the construction and operation of the BR-5 plutonium oxide reactor (5000 kW). Work on a fast reactor with an electrical output of 50,000 kW and a thermal power of 250,000 kW had been dropped (see *Worldview*, July p 55). At present, nuclear scientists and engineers were thinking of designing a larger reactor of 800,000 kW or more.

United Kingdom Dr Derek Smith stated that designs of fast reactor power stations for use in the 1970's were now being studied. It was then likely that the electricity generating boards would be looking for power stations with outputs of about 1000–2000 MWe with two or more reactors per station.

He added that British scientists and engineers were looking towards the construction of 1000 MW commercial fast reactors in the 1970's. A prototype reactor, which might be 300 MWt or more would probably be built by the end of this decade. (Meanwhile, it is understood that power testing of the Dounreay Fast Reactor will start soon and that a power of several watts will be reached by the New Year.)

France Cadarache is the centre of fast reactor activity. The experimental reactor, RAPSODY, was due to be operational by the end of 1964. A second step, according to Dr G. Vendryes would be the building of a 250MWt reactor towards the end of the present decade which would help in designing a true fast neutron power reactor prototype. Stress would continue to be laid on plutonium fuel.

United States Aims of the US programme, in general, were for an advanced power plant to start construction in 1964 and an economic fast reactor to operate in 1971, said Dr Bernard Spinrad of Argonne National Laboratory. He also gave a short review of Argonne's work in this field which is based on the EBR-2 reactor at present under construction.

Euratom sets up fourth research centre

Brussels A fourth Euratom Research Centre has been set up in the Netherlands. This follows the signing of an agreement with the Dutch Government transferring the 20 MWt high-flux test reactor at the Petten Centre and the site to Euratom. Within three to five years, Euratom will set up all installations required for a modern nuclear research centre.

Euratom will co-ordinate its work with the Netherlands Nuclear Research Centre and a joint investment policy will be carried through. Total investment will be $18 million of which Euratom's contribution will amount to $10 million. Running costs will be borne by Euratom.

For a transitional period of four years, the irradiation programme will be carried out jointly by Euratom and the Netherlands Research Centre. Housing will be provided for Community staff and the Euratom centre will be integrated with the Dutch facilities.

Other Euratom research centres are situated at Mol, Belgium; Ispra, Italy and Karlsruhe, West Germany.

• **CEGB oil station** A £10 million oil-fired power station is planned for Fawley, Southampton Water. The CEGB says that if building permission is granted, plans for a nuclear power station at Hampstead, Isle of Wight, will be deferred.

• **Ionizing radiations** Six orders were published by the Ministry of Labour on September 15 prescribing the particulars to be contained in the radiation dose records kept under paragraph one of Regulation 24 of the Ionising Radiations (Sealed Sources) Regulation, 1961.

Portugal nears decision on power station

Lisbon A decision on whether or not to build a small nuclear power plant is expected to be taken by the Portuguese Government at the end of this year or in early 1962. This follows the completion of studies by the Companhia Portuguesa de Industrias Nucleares which concluded that investigations should start soon on the possibility of building a small nuclear powered station.

The studies were carried out over the past two years to determine the electrical needs of the country and the part that nuclear power could play. They commented favourably on the competitive future of nuclear energy in Portugal and on the prospects of a 40%-50% participation in a nuclear project by industry.

• **Swedish plant closes** The AB Atomenergi uranium plant at Kvarntorp will close at the end of February, 1962, one year earlier than calculated. The main reason is the lack of new uranium deposits at hand to warrant continued operation at Kvarntorp.

• **Amersham incident** Phosphorous-32 was found to have been released from one of the chimneys at the AEA's Radiochemical Centre at Amersham recently. This happened during routine production for medical purposes. There was no danger to public health.

• **NIMROD ion gun success** The first proton beam to be accelerated to the design energy of 15 MeV has been obtained from the linear accelerator injector which forms the first stage of the 7000 MeV proton synchrotron, NIMROD, at Harwell.

• **German nuclear investment** Regret at the comparatively low expenditure on nuclear power is expressed in the annual report of the German Federal Federation of Industries (FFI).

• **Newcastle critical assembly** Rutherford College of Technology, Newcastle, is building a sub-critical assembly after waiting four years for Government authorization. It will be the first sub-critical assembly in any UK College of Technology.

Norwegian reprocessing plant starts operations

Kjeller, Norway A pilot uranium reprocessing plant at the Institutt for Atomenergi, Kjeller, has been opened by the Dutch-Norwegian Joint Research Establishment (JENER). At first, the plant will process fuel from the first fuel loading of the JEEP research reactor.

At the same time, it was announced that the zero energy facility NORA at the Institutt operated for the first time on June 9. NORA is intended primarily as an instrument for reactor physicists and the design has been made as flexible as possible.

A further reactor, JEEP-II, of 2MWt is to be built at the centre.

UK export controls

London Export control has been imposed on tritium and certain tritium compounds, specified manufactures of beryllium and hafnium metal and alloys and compounds by the U.K. Government. The changes came into force on September 12 and result from amendments to the list of goods subject to embargo for the Soviet bloc and China, says a Board of Trade announcement.

Other changes include the removal of export control from specified zirconium oxide, irrespective of destination, and from specified vacuum induction furnaces if destined for the Commonwealth, the Irish Republic or the USA.

In addition, the description of goods to which export control applies have been modified on a number of items including centrifuges, dosimeters, heat exchangers, reactors, and electronic and precision instruments and apparatus.

WORLDVIEW

OVERSEAS

Seven tenders for Indian station

Bombay Firms in Canada, France, the United Kingdom and the USA have submitted a total of seven tenders for the design and construction of the 300 MW nuclear power station at Tarapur. It is expected that the detailed evaluation and assessment of the tenders will be completed in about five months, says an official statement from the Indian Department of Atomic Energy.

The names of the firms submitting tenders have not been released by the Department though the General Electric Company and the English Electric Company are known to have submitted tenders. One of the French tenders, incorporating a concrete pressure vessel, is said to come from a group including SCAM, Alsthom and Constructions Mecaniques et Chantiers de l'Atlantique.

The official release adds that consultancy services have been offered by the atomic energy authorities of several countries. It is hoped that construction work on the station will begin by March 1962. In the meantime, considerable site preparation and ancillary works are in progress.

Philippine plant is economic prospect

Vienna A relatively large nuclear power plant installed late in the 1960's on the island of Luzon, in the Philippines, might be economically competitive with a conventional power plant of the same size, says a recent report by the International Atomic Energy Agency.

Its conclusion, based on certain stated assumptions, is that 'nuclear power plants of the 2 × 100 MW or 150 MW sizes may be competitive (in the Luzon grid) with oil-fired plants having an average lifetime-fuel-cost of 40 cents per million BTU or $2.40 per barrel. When oil prices go above this figure, the area of competitiveness for nuclear power is greatly enlarged. Therefore, considering that the present price of fuel oil is approximately 38 cents per million BTU, one can conclude that the use of nuclear power in the Luzon grid towards the end of the 1960's deserves serious consideration'.

The report was prepared by a three-man Agency mission which visited the Philippines in October last year to study the prospects of nuclear power in that country over the next decade. It was specifically concerned with the prospects of installing a nuclear plant in the electric power grid which serves a major part of the island of Luzon.

US—Euratom Act

Washington Minor amendments to the US-Euratom Cooperation Act of 1958 are contained in a Bill passed by Congress. In their comments on the changes, the Joint Committee on Atomic Energy says that one of the amendments makes it clear that the AEC is authorized to publish criteria for determining maximum fuel element costs and minimum fuel element performance in connexion with the Euratom fuel cycle guarantee programme.

The amendment provides for the AEC to establish a formula which permits each manufacturer to calculate on the basis of his particular fuel element and reactor design, fuel element costs for comparison with costs computed on the basis of the US guarantee limits. This will determine the eligibility of his proposal for a guarantee.

The Committee adds: 'It should be made clear, however, that the minimum fuel element life guarantee of 10,000 megawatt days per ton and maximum fuel fabrication guarantee limit of $100 and $140 per kilogram of contained uranium for stainless steel and zirconium elements, respectively, will still be effective.'

• **Graphite for Hanford** Nearly five million lb of nuclear graphite for the New Production Reactor at Hanford has been produced and shipped by National Carbon Co. The order was worth $2 million.

• **Hanford plant saga** The US House of Representatives has rejected a compromise proposal to install one electric generator at the Hanford New Production Reactor. The vote sent the entire AEC authorization measure back to a conference with the Senate. The latter body originally approved a $95 million request for two generators at Hanford capable of producing 800 MWe. (See *Worldview*, September, p 58 and August, p 58.)

• **Australian reactor?** The Assistant General Manager of the Southern Australian Electricity Trust is reported to have said that the possibility of building a 180 MW nuclear power station is being considered.

• **Peruvian reactor project** Plans reported to have been submitted to the Atomic Energy Contol Board of Peru by GE of the US provide for a nuclear reactor capable of generating power for an industrial development in Peru's southern region by using Lake Titicaca for irrigation and cooling.

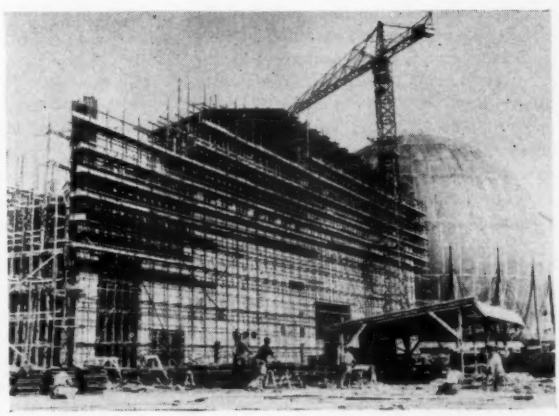
• **Japanese fuel order** The Japanese Atomic Energy Research Institute is to order the second fuel loading for its 10 MWt JRR-3 reactor from the Japan Atomic Fuel Corporation. The first fuel loading was handled by AMF Atomics (Canada) Ltd. Loading of the second charge is scheduled for April 1963.

• **New particle discovered** A new elementary particle of matter, the omega meson, has been discovered by scientists at the Lawrence Radiation Laboratory, California. The particle, whose existence was predicted several years ago on a theoretical basis, has a lifetime of a hundred billionth of a second. It has no electrical charge.

Companies share PWR

New York San Diego Gas and Electric Company is to take a 20% share of the cost of the 375 MW pressurized water reactor station to be purchased and operated by Southern California Edison Company. (See *Worldview*, June, p 57.)

The companies will be paying about $10 million for land and improvements and about $68 million for the Westinghouse PWR and equipment to supply steam to a 375,000 kW turbo generator. The plant is expected to be in operation by July 1, 1965.



SENN FUEL The largest single order of uranium ever placed with the UASAEC's Oak Ridge Gaseous Diffusion plant (12,370 lbs valued at some $9 million) is that for the Italian 150 MW (BWR) Senn project seen at the right

Cross Section by GRACCHUS

ONE OF THE INTERESTING developments in the past month has been the announcement from India that seven tenders have been received for the 300 MW, two reactor, Tarapur station. It had been expected the four to five tenders would be submitted (two from the UK, one from Canada and one/two from France). What had not been expected was any tender(s) from the United States. When the Indian Department of Atomic Energy invited bids, natural uranium was specified in the notice. However, the possibility of enriched uranium reactors was not ruled out; proposals for these could be submitted at the tenderer's own risk . . . ' the purchaser reserves the right to reject any or all such tenders '. India's coolness towards this type of fuel and the US Department of State's intimation that the US would not offer financial assistance towards the project has not apparently deterred American industry. No names of firms have been released from India and while the US firms are not known, it is believed the French bid originates from a group including Alsthom and SCAM. Rumour has it that this design uses a concrete pressure vessel and an improved method of burst slug detection.

A THIRD UN CONFERENCE on atomic energy is unlikely to be held in 1963 if present indications are any guide. The heavy expense the UN has had over the Congo makes it unlikely that the General Assembly will sanction further large sums for a conference in Geneva. In addition, no trace of the item can be found in the provisional agenda for the 16th session of the General Assembly which started its meeting in September. First indications that the UN was thinking of a third conference, to follow those held in 1955 and 1958, came in April 1960 when the Secretary General decided, on the advice of his Scientific Advisory Committee, to recommend to the General Assembly in the autumn that another major conference be held in Geneva in 1962. After further study, the Scientific Advisory Committee decided in November 1960 that the third conference should take place in the first two weeks of 1963 in Geneva. The matter was not discussed at the 15th session of the General Assembly which allocated the matter to one of its committees. This body was to look further into the matter. Apparently, no decision has yet been reached though the item in question may be buried in one of the reports to be submitted to the Assembly at its present meeting.

THOUGH GOVERNMENT CIRCLES have in the past shown some interest in the UK joining Euratom, the Atomic Energy Authority has maintained that joining, on the whole, would be a disadvantage. Their attitude has not changed despite the application by the UK to join the Common Market. The basis for the AEA's stand against any link-up is that there is already a free exchange of information existing through the present working arrangements. Being in Euratom would lead to a loss of independence, loss of defence flexibility and, in the short run, directed research might impede the UK's own efforts. My own feeling is that these objections certainly do not seem to have hindered the French and that the nuclear industry in Member countries seems to have benefited from the spreading out of research contracts. However, now the decision has been made to apply for European Community membership, these objections are likely to be overridden in the general discussions that will take place.

A CONTROVERSY over the economics of nuclear power has broken out in Sweden between the Swedish State Power Board and AB Atomenergi. The conflict is over the proposed nuclear power station at Marviken. AB Atomenergi thinks the station should be built as soon as possible so as to be operating by 1967. However, the Power Board, which has to show a return on investments, is stricken at the idea of having to finance and operate a station of 105 MW which would cost some £27 million. The result would have to be an increase in electricity prices. The Board also says the chance of nuclear power competing with conventional sources before 1975 is small and therefore thinks it unnecessary to have a nuclear station by 1967. AB Atomenergi who do not argue about the Board's figures point out that this station would be a logical step forward from the Agesta station. Furthermore, if the plant were not built, it was likely that design and development teams would break up and when the time came for a go-ahead on nuclear power, the trained personnel would not be available. The decision as to whether the Marivken (R4) plant will be built now rests with the Swedish Parliament.

A BRITISH ATOMIC FORUM is still a faint possibility, I am told. The idea is not yet dead despite the lack of meetings to follow up the initial ones convened by the Federation of British Industries. I believe plans are in hand for another meeting in the New Year which should resolve, one way or another, the question of setting up such a Forum. The basic conflict is apparently between the larger firms who are content with the present situation and the smaller firms who see the advantages to be gained. Personally, I have often wondered why Britain, of all the major nuclear countries, should be the one nation without such a Forum.

On Record

' *Our danger, it seems to me, is that we have had too many scientists of the same point of view in high advisory posts—the danger of solitary viewpoints rather than solitary czars. Although at loggerheads on such issues as weapons testing, most of the advisers seem to be cautious about going into hardware projects . . .*'

Congressman Melvin Price, chairman, subcommittee, research and development, Joint Committee on Atomic Energy, at a recent meeting of the Washington Chapter of the American Nuclear Society.

I hear that . . .

. . . a **CEGB takeover** of the AEA's Reactor Group is still being discussed in industry circles despite an official denial from the chairman of the AEA.

. . . a **number of staff** in the AEA's northern establishments are shortly to leave. This has prompted the ' unkind ' remark that the only people who will be left will be ex-Ministry of Supply personnel.

. . . **indemnity problems** have delayed the shipment of the core for the Belgian BR-3 pressurized water reactor.

. . . **on-off labour troubles** still plague work on the AGR but that so far the end-year date for criticality is still being maintained.

. . . a **new industrial** consultative committee, similar to BICEP, is to be set up by the AEA and industry. It will deal with heavy water reactors.

. . . **dissatisfaction over Dragon** project information has again become apparent in European industrial circles. This is not due to individuals but to the organization which leaves industry feeling that it has been relegated to the role of a subcontractor and nothing more.

WORLDVIEW NEWS FEATURE

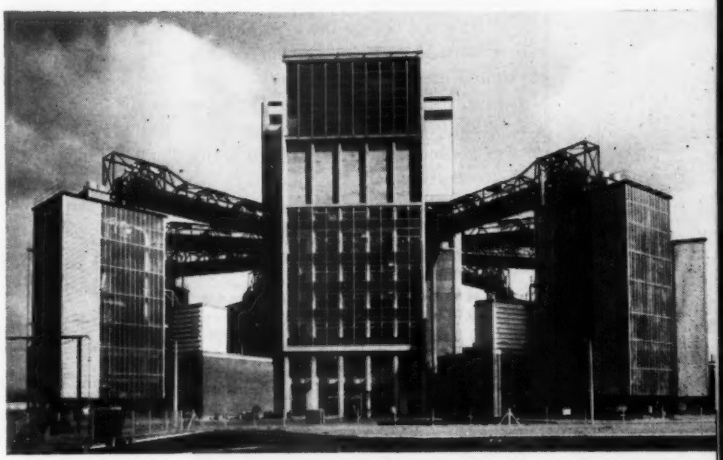
ON BERKELEY & BRADWELL

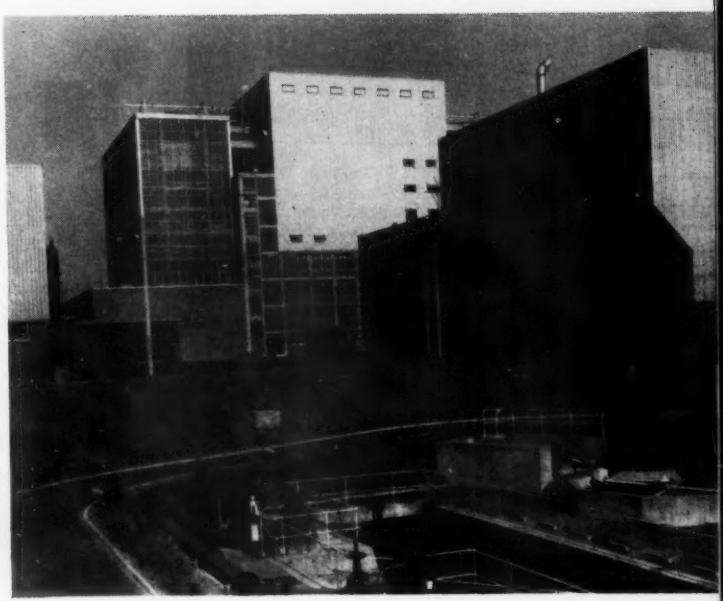
ENGINEERS AND SCIENTISTS of The Nuclear Power Group achieved an historic 'first' when they brought to criticality the No. 1 reactors at Britain's first two nuclear stations specifically built for electricity generation (see pictures at right). This first step towards commissioning of Bradwell and Berkeley nuclear power stations was, in the main, received quietly in the world's press, despite the significance of the event.

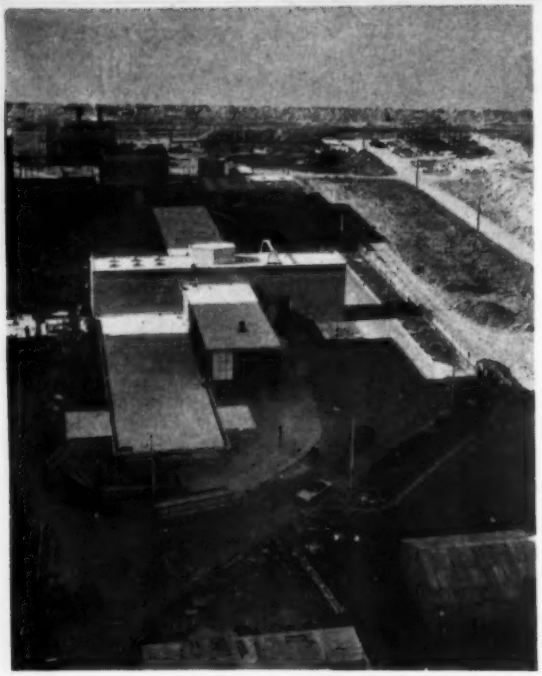
The approach to criticality took place when fuel loading started in August—on the 12th at Berkeley and on the 14th at Bradwell. Five days later, on August 19, criticality was achieved at Bradwell to be followed on August 27 by Berkeley's No. 1 reactor. Before fuel loading started, a series of stringent tests took place. After this, at Berkeley in this instance, 24 control rods in the central region of the core, out of a total of 132, were lowered and locked in the DOWN position. They could not be withdrawn when manual fuel loading took place. The remaining 108 control rods were held in the UP position, ready to drop instantly in case of an emergency.

The fuel was then brought in special fuel carriers to operators standing on top of the graphite core structure inside the reactor vessel. They unloaded the elements from the carrier, placed them in a wheeled trolley and took them to the channel to be loaded. The first channel to be loaded was in the centre of the cylindrical core. Fuel loading continued outwards, maintaining a cylindrical pattern. (At Berkeley, 13 fuel elements were stacked vertically in each channel and at Bradwell, eight per channel.)

After 300 (out of the 3275 at Berkeley) channels were loaded, the operators left the reactor vessel. This was then sealed and the 24 control rods withdrawn. On the reactor charge face, physicists read the neutron production in the core from instruments. This measurement was taken and then the 24 control rods were again lowered into the locked DOWN position, the vessel unsealed and a further 100 channels manually loaded. When this point was reached, the operators once again withdrew and the neutron production was again recorded. The operation was repeated with the number of fuel channels being loaded between each test becoming fewer. These tests enabled a curve to be made of neutron production against the number of channels loaded.

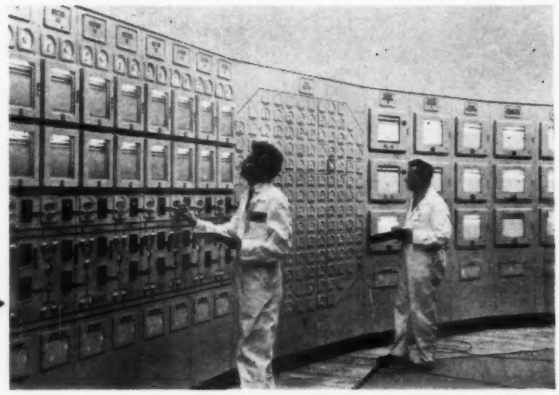






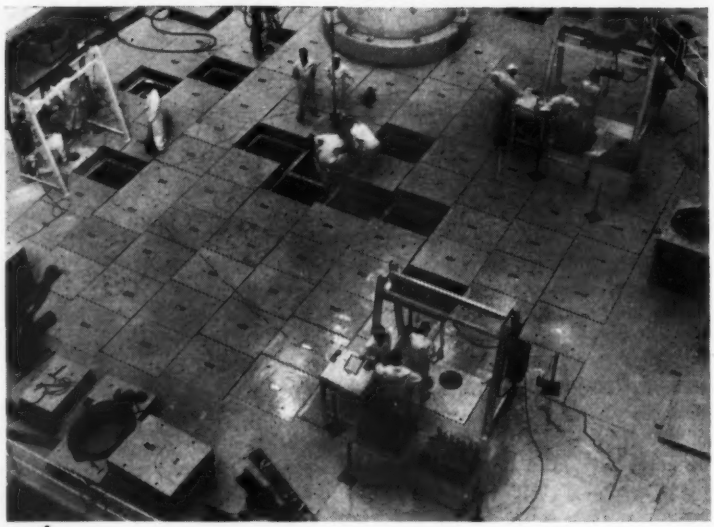
The main C.W. pumphouse area at Bradwell

BRADWELL



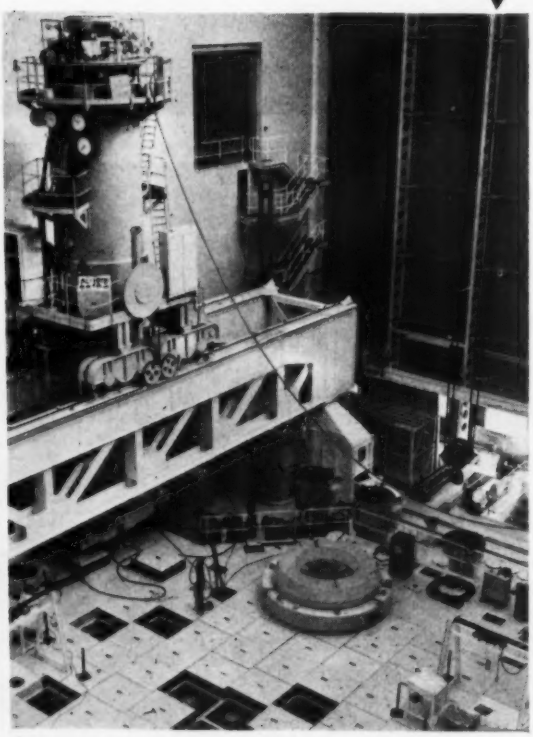
Checking instruments in the main control room for No 1 reactor

From this curve, a forecast was made of the total number of channels remaining to be filled before the critical mass was attained. The loading procedure continued until this point was reached. However, the No. 1 reactor at Berkeley was still not allowed to 'go critical' until a predetermined point in a series of tests carried out at that time to check the various nuclear design calculations. For Berkeley, approximately 660 of the 3275 channels were loaded

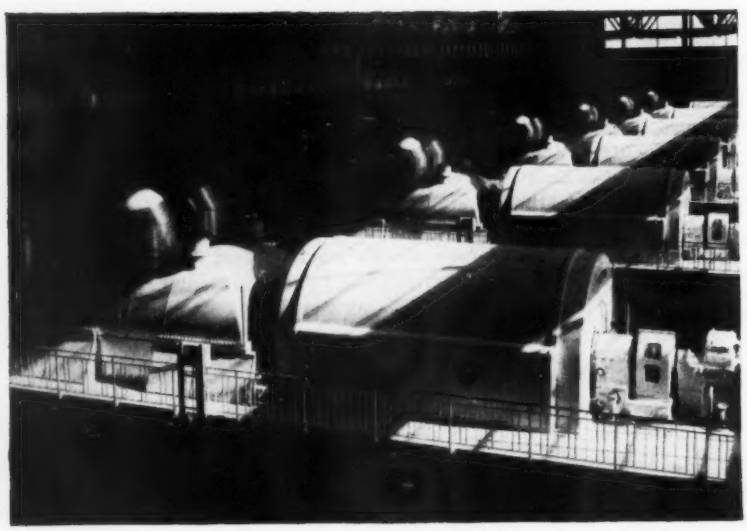


Fuelling operations on No 1 reactor, taken after criticality was achieved

One of the two charge/discharge machines on No. 1 reactor pile cap



The six main turbo generators



BERKELEY

A general view of Berkeley nuclear power station

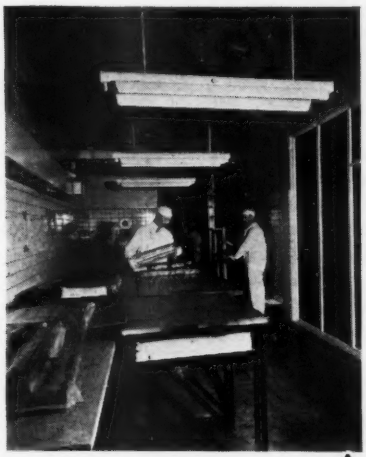
to reach criticality and at Bradwell 464 of the 2564 channels. In weight, this represented for Berkeley approximately 50 tonnes compared with a total of 232 tonnes of fuel required to bring the reactor to the fully operational condition. For Bradwell, corresponding figures are 38 tonnes and 235 tonnes.

Following criticality, intensive tests have been carried out to obtain information concerning the nuclear data for the critical core. According to latest reports, work is continuing to schedule at both stations. This means that loading of fuel has again started by hand, punctuated by routine tests as before until both No. 1 reactors are loaded with the full operational load of fuel.

On the charge face, an Inspector checks the fuel element numbers; the carrier is then lowered by an electric winch down inside the pressure vessel

The controls of No 1 reactor in the main Control Room being checked after criticality had been achieved

A corner of the fuel element store at Berkeley showing newly received fuel elements being examined before acceptance



In the Fuel Preparations Room of No 1 Reactor fuel elements are inspected and loaded onto a triangulated carrier. From here they are pushed to the charge face for loading into the core.

Looking down on the charge face of No 1 Reactor showing loading of the fuel in the background

Will we reach the point where it is not much use developing a new metal if it cannot be welded?

New developments in the welding industry

by R. G. BURT, O.B.E., B.Sc.(Eng.), M.I.Mech.E., M.Inst.W.,
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INDUSTRIAL USES OF WELDING PROCESSES have grown so rapidly in such a short time as to be one of the phenomena of the nuclear age. An increasing effort is being put into research and development but so many problems still remain to be solved, while new ones are continually arising, that even more effort is needed if this country is to maintain its industrial status.

This article will review briefly a selection of these numerous developments and problems.

PROCESSES

Despite the development of new and improved welding processes, a very large proportion of welding operations are still carried out by the manual, metal arc, coated electrode process; it is obvious that this position will continue for some time. Developments here have been mainly in the introduction of new and improved types of electrodes which enabled higher deposition rates, better quality welds in an increasing range of materials, an increasing use of a.c., and other advantages to be effected. Research work which revealed the significance of hydrogen as a major factor in cracking problems led to developments of the basic coated, low hydrogen type of electrode. This enabled welds of the highest quality to be made, not only in mild steel, but also in the higher carbon steels and low alloy steels of both the high tensile and creep resisting types. Recent achievements in heavy fabrication owe much to these developments. 'Controlled hydrogen' electrodes with a coating of other than the basic type have also been developed. Several types of electrodes having an appreciable amount of iron powder incorporated in the coating have been developed and these offer advantages when used in appropriate applications.

Examples of friction welded ¾-in dia. mild steel bar; top as-welded; middle tensile tested; bottom bend-tested (Fig. 1)

There has been considerable expansion in the use of automatic welding; developments have been made in the processes themselves and in the design of special purpose machines, e.g. for the automatic welding on site of horizontal and vertical butt welds of storage tanks, the fabrication of large pipes, the simultaneous welding on both sides of stiffeners to large bulkheads, etc. The use of the submerged arc process has been extended to materials other than mild steel, e.g. stainless steel, hard surfacing applications. Russia claims to have developed submerged arc welding of aluminium, but in this country the inert gas shielded processes have been more highly developed for aluminium and its alloys. The open arc automatic welding processes with fluxed electrode have also undergone development. In addition to the type in which the flux is in the form of a coating on the core wire, other types have been developed such as that in which the flux is contained in a metal sheath forming the electrode. The development of supplementary CO_2 shielding has also produced beneficial results.

The gas shielded welding processes have been described as a major breakthrough in the development of welding processes. The first to be introduced was the inert gas shielded, tungsten electrode process (popularly known in this country as the 'Argon Arc'). Early difficulties were experienced. In welding aluminium and other metals having a quick-forming, highly tenacious oxide film, d.c. supply was found unsuitable as with the electrode negative the oxide film was not dispersed and with the electrode positive the tungsten electrode became overheated and malformed, and contamination of the weld with particles of tungsten was liable to occur. The use of a.c. supply offered a solution but there were difficulties to be overcome. The arc tended to fail to re-ignite after the current passed through zero unless a high open circuit voltage was employed; even when re-ignition was ensured by using a high open circuit voltage transformer, injecting a high frequency spark, or other means, the current wave form was asymmetric, less current flowing for a shorter time in the positive than in the negative half cycle. Investigations in which the Electrical Research Association in collaboration with the British Welding Research Association

Brittle fracture wide plate test on a 3-in thick shell plate with branch welded in. Tested in the as-welded condition at—12° C. Before fracture the circular branch elongated 6% (Fig. 2)

played a prominent part provided a solution to these and other problems. The introduction of the tungsten electrode process was followed shortly afterwards by that of the inert gas shielded metal arc process in which the electrode is in the form of a wire, fed continuously through a nozzle conveying a stream of argon or other inert gas. Considerable research and development work has been done on this process and its applications including : arc phenomena, the effect of generator characteristics, mode of metal transfer under various conditions, effect of variables including arc volts, current, current density, wire diameter, wire feed rate, wire composition, burn-off rate. This work has resulted not only in improvements in both of these processes and their equipment, but also in higher quality welds and the increasing scope of their application to a greater range of materials and thicknesses of section.

Work has also been done on the use of other gases and mixtures of gases for shielding. For example, nitrogen and argon/nitrogen mixtures have been used in the welding of copper; and recent work has shown that an argon/nitrogen mixture in suitable proportions is beneficial in the welding of copper of thick section.

Development of the bare wire, CO_2 shielded process in welding ferrous materials is comparatively recent in this country. In the early stages excessive spatter and difficulty of operation in other than the down hand position were among its disadvantages. Recent research and development work has overcome these and high quality welds, in all positions and free from spatter, can be produced. Numerous production applications have been developed in welding steel from 20 s.w.g. to 3 in thick.

The electron beam welding process has also been introduced fairly recently. Space will not permit a description of the process but literature on the subject is available. Development in the use of the process seems likely to be in fine, highly specialized applications in which time and cost are less important factors, rather than in a more general field.

Some materials (e.g. aluminium) can be joined by pressure alone without the application of heat (cold welding). With other materials pressure welding is facilitated by the application of a certain amount of heat. Investigations of the fundamentals of the process which has useful applications have been made by Tylecote and others. One feature of the process which is sometimes a disadvantage is the high degree of deformation required to ensure sound welds, (e.g. 70–80% for the cold welding of aluminium).

Ultrasonic welding, though known for several years, seems slow to develop in this country although there would appear to be a useful field of application. This is particularly so where the application of heat is undesirable and the high deformation in cold welding cannot be tolerated. The process in which components to be joined are subjected to ultrasonic vibration under pressure is also useful in joining thin materials, components of greatly differing section thickness and dissimilar materials.

Friction welding is being developed extensively in Russia and China and this form of pressure welding is being in-

MORE RESEARCH AND DEVELOPMENT NEEDED

Few, if any, of the manufacturing processes used in industry can show such an extensive and rapid development as that which has occurred in recent years in welding in its various forms. This has been not merely in the amount of welding done, which in itself is remarkable, but also in the introduction of new and improved processes, equipment and techniques, the use of welding for an ever increasing range of materials and applications; and the increasing importance of such applications requiring welds of the highest quality to meet severe service conditions. Welding has been a major factor in enabling outstanding engineering developments to be accomplished which would otherwise have been most difficult, impracticable, or even impossible to achieve. Examples come readily—the development of nuclear power, the construction of conventional steam raising plant of ever increasing size, pressure and steam temperatures, construction of large hydro-electric plants, the development of the gas turbine and jet engine, etc. The lighter engineering industries have also benefited; for example, developments in the electronic industry owe much to welding techniques developed for miniature assemblies. Development in the use of welding is, however, not only due to the technical advantages it could offer, but also to a growing appreciation of other advantages, particularly economic, e.g. decreased time and cost of production, economy in the use of materials, etc.

This upsurge in the use of welding inevitably brought a large number and variety of problems; the position was accentuated by a heavy back-log of problems requiring solution as welding applications had already outstripped the general level of basic knowledge of the subject. There was also a great shortage of technical man-power. So great was the pressure that often an *ad hoc* solution was all that could be achieved as there was insufficient time, man-power and finance available for a more fundamental investigation. The increasing number, importance and urgency of problems relating to welding stimulated research and development, not only in organizations such as the British Welding Research Association which has more than trebled its annual income and expenditure in the past ten years, but also in many commercial undertakings. This growth has been rapid but there are no grounds for complacency in the present position; on the contrary, more effort is needed if this country is to maintain its place among the industrial nations—as the following particulars show. In 1959 the British Welding Research Association circularized its members with a list of 54 proposed projects for research asking them to allocate priority points to them. In the replies, the priorities agreed closely with the Research Board's assessment and 104 additional items of priority were also suggested. Examination showed that to take up even fifty of the projects would require the research staff to be doubled. It is to be noted that these were all research projects and quite apart from the very large number of short term investigations of production problems carried out for the Association's members.

vestigated in this country. The surfaces to be joined are rubbed together under pressure, thus producing heat. When the interfaces are up to the appropriate temperature, the relative motion is stopped and an upset pressure applied. The time taken to make a weld is quite surprisingly short. Established applications include joining bars, rods, pipes, tubes and tube ends to plate (Fig. 1). It also appears that in addition to steel several other materials can be welded by the process.

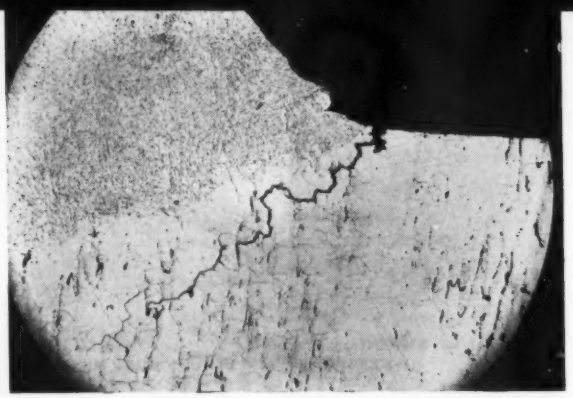
The 'electro-slag' process originated, and has been extensively developed, in Russia. Introduced to this country comparatively recently, it is being rapidly developed and is already in use in production work for welds to a high standard of requirements. The process offers considerable technical and economic advantages, in the welding of the heavier sections of steel; further development in the use of the process is anticipated.

In the resistance welding field, developments have been largely in improved controls of the welding variables: time, current, current waveform, post weld heat cycles, etc.—thus enabling consistent higher quality of welds in a wider range of materials. Other developments have been the 3-phase spot welder, the large press multi-spot welding machines used in motor car body manufacture and similar applications, and a variety of miniature machines for fine work, e.g. micro-butt welders for butt welding fine wires, small stored energy discharge machines useful for joining thermocouple wires, joining the ends of wires to surfaces and a wide range of other applications. Development of these miniature machines has been of great value to the electronics industry and in other requirements for fine work. Extensive fundamental work has been done on the spot welding of aluminium and certain of its alloys and Codes of Practice established. The spot, seam and projection welding of steels other than the low carbon mild steel type, certain stainless steels and the nimonics is at present under investigation.

MATERIALS

Welding of mild steel is generally regarded as a relatively straightforward operation. While this is so in the more simple applications, the increasing demand for welds of higher quality and in greater thicknesses of material which in itself gives rise to problems, has produced a number of problems which have become more acute. Causes of the various forms of cracking, the effect of hydrogen and other elements (often present as traces) have been investigated and studies made of the metallurgical structure of not only the weld metal, but also the heat affected zone of the parent material. Extensive work has also been carried out on the higher carbon and low alloy, high tensile steels. In the latter field, investigations have included not only the causes of defects and conditions in which high quality welds can be produced, but also the development of higher tensile steels of weldable quality. In this connection the quenched and tempered weldable steels are of interest and importance. While much valuable information has been gained, facilitating the production of high quality welds in an increasing range of material, knowledge and understanding of the various problems is by no means complete. However, the increased funds for research which have become available recently are enabling the more fundamental aspects of the problems to be investigated.

In this field of the mild and low alloy steels, a problem of vital importance, which has been and still is the subject of extensive investigation, is that of brittle fracture (Fig. 2). Attention was first focused on this by the failure of certain welded ships built during the last war. It was soon evident that this problem was not confined to shipbuilding and that past failures, which had been ascribed to other factors or unknown causes, were cases of brittle fracture. With the rapidly developing increase in size of welded constructions and thickness of section employed, coupled with the necessity for utmost reliability, the acuity of the problem became all the greater. The importance of this subject to the nuclear power industry, as exemplified by the catastrophic failure during construction in France of a reactor containment vessel, cannot be over-emphasized. It is gratifying to note that in investigations of this important problem this country holds a leading position. Work done receives international recognition and lines of approach and methods developed, particularly by the British Welding Research Association, are being followed in several countries.



Cracking in the heat affected zone of 18 Cr/12 Ni/1 Nb type steel × 50 (Fig. 3)

The high alloy steels have also given rise to problems of which particular reference may be made to the recent one of heat affected zone cracking of stainless steels of the 18Cr/12Ni/1Nb type such as are used in applications where good corrosion resistance and high temperature strength are required (Fig. 3). Work on this is still proceeding but has already yielded valuable information which is leading to a wider investigation of a range of stainless steels.

Extensive work has been carried out on the welding of aluminium, the wide range of aluminium alloys and certain magnesium based alloys. These investigations have been closely associated with and facilitated by research and development work on the inert gas shielded processes; and have covered not only the elimination of cracking and other defects, but also improvement of the strength of welded joints in these materials as in many cases even sound welds were found to give joints inferior in strength to the parent material. Static and fatigue tests have been carried out and the significance of various types of weld defects and means of improving fatigue strength studied. In certain cases a filler metal of a composition different from that of the parent material is used to obtain sound welds of reasonable strength. The corrosion behaviour of such welds is being investigated. Although the magnox fuel can has been in service in the Calder Hall type of reactor for some time, the development of improved methods of sealing the cans is continuing.

Welding problems and developments have also had to be dealt with in a wide range of other non-ferrous metals, e.g. copper in its several grades, copper alloys, nickel, nickel alloys. Also, new materials are being more frequently developed to meet the ever increasing requirements of developments in various branches of industry, many of which arise in connection with nuclear power. Elements which, a few years ago, were mainly of scientific interest, or were used in

small percentages in alloys, are now being brought into service in new forms as the major constituent in alloys or as the unalloyed metal, e.g. titanium, niobium, tantalum, beryllium. The introduction of these new materials usually entails investigation of their welding properties. So ubiquitous has welding become as a fabricating process that recently it was said—' Nowadays it is not much use developing a new metal if you cannot weld it '.

DESIGN

A major handicap in the development of welded construction has been a lack of knowledge of basic principles of design for such work and a widespread lack of appreciation of the need for such knowledge. Many cases of failures, uneconomic and otherwise unsatisfactory constructions, can be attributed directly to this; there is no doubt that, particularly in the earlier days, such cases were the cause of much prejudice against welded construction. In addition, the increasing severity of competition, the increasing size of welded fabrications and the thicknesses of section employed, new forms of construction and service conditions requiring the utmost reliability, all indicated the need for examining the provisions of existing codes of practice, specifications and design procedures, testing the validity of existing regulations, theories and assumptions, providing more precise data on which designs could be based, and ensuring a more effective use of material.

Extensive work has been in progress in this field for several years; and that of the BWRA on pressure vessels and pipelines is of special interest and importance to the nuclear power industry. Pressure vessel investigations have been mainly concentrated on determining the magnitude and distribution of stresses around branches and nozzles and other openings and the effectiveness of present conventional and other forms of reinforcement in reducing stress concentrations. Full size and scale models have been used in these investigations which cover a wide range of diameter/thickness ratio. In addition to this fundamental work, the techniques developed and experience gained have been of considerable value in solving several design problems of an *ad hoc* nature. The original work which was carried out in mild steel constructions has now been extended to investigating the use of high tensile steels in pressure vessel construction; and future studies are likely to include aluminium also.

Pipeline investigations have included the flexibility of bends of both the smooth radius and gusseted types, the magnitude and distribution of stresses in bends, tees and other details under various types and combinations of loading, e.g. internal pressure, in-plane and out-of-plane bending, torsion (Fig. 4). Fatigue testing has also been an important feature of these investigations.

Fatigue test of gusseted type bend subjected to out-of-plane loading (Fig. 4)

Research relating to design has covered other fields. The fatigue aspect of the design of welded constructions is of great significance and lack of appreciation of this has been the cause of many service failures. Several of these have been investigated, modified designs produced and their superiority proved by testing. The fatigue strength of various types of welded joints in several materials and means of improving it in certain cases have been studied; and the influence of weld reinforcement shape and various types of weld defects investigated. Stress analysis under static and dynamic loading of several types of constructions has also been carried out and has yielded valuable information.

The development of the plastic design theory is also a matter of considerable importance as in many cases it offers a more ready and precise solution than earlier methods and also appreciable economy in material.

TECHNICAL EDUCATION AND TRAINING

Much has been said and written in recent years on the manner in which technical education and training in the United Kingdom was falling behind that in other countries. This was particularly evident in the field of welding. Courses, mainly for operators and supervisors, operated by welding equipment manufacturers, always had waiting lists and facilities for teaching welding subjects at Technical Schools were inadequate; but it was at the advanced levels of technical education and training that the deficiency was most acute. Pioneer work in this field was done by the British Welding Research Association shortly after its formation. In addition to establishing valuable links with Universities and Technical Colleges and stimulating interest in subjects related to welding, the Association organised and ran for seven years, an annual Advanced Summer School at Ashorne Hill, providing courses usually of a week's duration. Applications to attend these courses always greatly exceeded the number that could be accommodated. Shortly after The Institute of Welding moved to its present building, responsibility for this educational work was transferred by the BWRA to the Institute which organized its School of Welding Technology and has now for four years been providing courses, usually of a week's duration, throughout the autumn, winter and spring months. Courses have also been organized in provincial centres.

In recent programmes of expansion of Technical Colleges and Schools, increased provision is being made for teaching subjects related to welding. Such subjects are also being included to an increasing extent in University Graduate and Post-Graduate Courses and Research work. Of particular interest is the Post-Graduate Course in Welding Technology at the College of Aeronautics, Cranfield, which has recently been organized.

Although it is gratifying to see these developments in the field of technical education and training, they are not enough. The problem is still one of the greatest importance and urgency. It is not just a matter of providing more lecture rooms, laboratories and courses. These will be of little value without an adequate and competent staff and of such there is already a grave shortage, due partly to the tendency of educational staff in technical and scientific subjects to be attracted to industrial appointments.

It is hoped that all those who can bring influence to bear will use it to the utmost to intensify efforts to improve the present technical educational and training facilities.

The exploitation of new systems and automatic processes is a boon to reactor engineers

Welding in nuclear power stations

by F. S. DICKINSON, A.M.I.Mech.E., A.M.Inst.W., Senior Welding Engineer, Reactor Materials Laboratory, Reactor Group, UKAEA, Culcheth

INDUSTRY IS BY NOW FAMILIAR with the general requirement that welds used in plant containing radioactive substances must be of virtually defect-free standard. This requirement, whilst evoking criticism from some quarters on the grounds of being over-cautious has, nevertheless, spurred both the development of equipment and techniques for the general benefit of the fabricating industry. Naturally, when a technique or procedure has been established to provide welds of the desired standard, control of quality can be better assured by making use of automatic systems. It is in this field that a number of interesting advances have been made in the last few years.

PROCESSES OF INTEREST

Welding methods which can produce the high quality seams needed for reactor pressure vessels and heat exchangers are

1. Manual metal-arc, in all positions
2. Submerged arc, (a) downhand position
   (b) 3 o'clock horizontal position
3. Electroslag, vertical position

Also of interest is the CO_2 shielded metal-arc, a method in which there are virtually no slag inclusions.

Automatic, or semi-automatic methods have been used on 50% of pressure vessel seams.

(a short basic description of these and other welding processes is given in this months Students' Page)

PROCESS PLANT CONSTRUCTION

In a large number of process vessels built on the heat exchanger principle, satisfactory heat transfer can be obtained by the simple tube/shell construction. Whilst the system of expanding and seal welding tubes to headers can be accepted for many of these, some in which highly corrosive and radioactive liquors are present on the shell side, make the associated crevice (Fig. 1*a*) an undesirable feature. Thus either an alternative design of vessel is demanded or a different technique of tube/header seal must be developed.

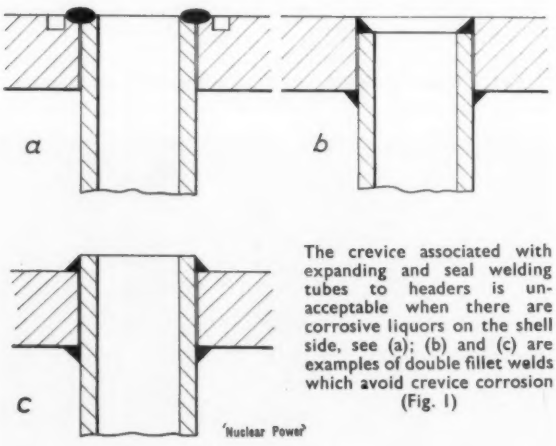
A change in design usually means a loss of process efficiency but fortunately techniques are now available which, whilst retaining the principle of tube/shell construction avoid the hazard of the crevice.

The simplest method of avoiding crevice corrosion is to weld on both top and bottom of the header plate (Figs. 1*b*, 1*c*). This generally dictates a pitch of tube greater than process efficiency can tolerate in order to provide the necessary access on the underside of the header, and is, therefore, hardly a satisfactory solution.

A second method is to make the crevice so large that it in fact ceases to be one and provides a free circulating path for the liquors. It then remains to develop a weld preparation and technique for guaranteeing uniform full penetration on the initial root run. Such a preparation is indicated in Fig. 2, and the use of simple fusion by the tungsten argon-arc process makes it an ideal application for an automatic head. Subsequent welds can be made by either manual metal-arc or inert gas metal-arc systems.

A more satisfactory method, however, is one in which simple fusion by the tungsten argon-arc process is again used under automatic control but this time from the centre of the tube in the manner indicated in Fig. 3. It will immediately be appreciated that this method has two marked advantages;

(*a*) that the header plate need only be drilled to accommodate the bore of the tubes instead of the o.d. and thus ligament efficiency is improved,
(*b*) that crevice free welds can be made on a smaller pitch



The crevice associated with expanding and seal welding tubes to headers is unacceptable when there are corrosive liquors on the shell side, see (a); (b) and (c) are examples of double fillet welds which avoid crevice corrosion (Fig. 1)

than is possible with the system shown in Fig. 2 and in fact offers virtually the same freedom that is possible with the expanded and seal welded method.

An inherent feature of the system is the location of the tube in a suitably recessed stub on the underside of the header. This serves to accurately align the members and at the same time to give a suitable heat balance between header and tube. This has unfortunately a number of drawbacks as follows :

(1) An extra machining operation is required on the header plate.
(2) The build-up of tube bundles between fixed headers is extremely difficult.
(3) The rectification of a weld failure in service is practically impossible.
(4) If the original stub is not completely fused, ' cross grains ' can be left and so provide a leak path if the quality of header material is poor.

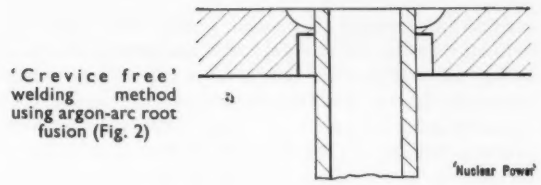
The machining of the underside of the header plate must be accepted as a requirement of the technique and set against the overall advantages, particularly in view of the consistency guaranteed. Designs are fortunately not all of the straight through type and thus many vessels make use of ' hair pin ' tubes which offer no difficulty to construction. The fact that repair is difficult presents no greater problem than is normally met with in ' hair pin ' type exchangers which are expanded and seal welded, and indeed by using automatic control of the welding process it is to be expected that the number of weld failures in service will be greatly reduced. The ' cross grain ' hazard can be overcome by correct development of stub length in conjunction with the appropriate welding current and thickness of tube wall and once established should be capable of accurate control.

Although this method has only recently been developed a number of materials have been satisfactorily welded. These include 1%Cr, ½%Mo; 2¼%Cr, 1%Mo, and 18/8/1 stainless steel, in addition to mild steel. Obviously each material will require an individual technique but once this is established a product should be possible having greater integrity than hitherto and might ultimately be produced at a comparable cost to the more usual systems now in use.

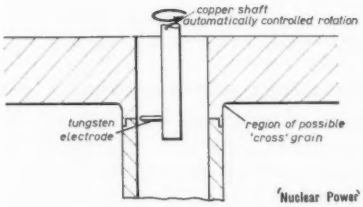
GAS-COOLED REACTOR CONSTRUCTION

The fundamental design of the gas-cooled graphite moderated reactor has been established with the construction of the Calder Hall and Chapelcross reactors in which the reactor pressure vessels of 2 in thickness were welded entirely on site by manual methods using rutile (titanium dioxide electrodes).

The nuclear stations under current construction for the CEGB are similar to the Calder Hall principle but in view of the increased output require larger and thicker reactor pressure vessels and corresponding heat exchanger capacity. With the exception of Berkeley, a spherical pressure vessel has been used to contain the reactor, and a study of Table 1 shows that although the diameter of sphere tends to remain



'Crevice free' welding method using argon-arc root fusion (Fig. 2)



Internal welding by argon arc (Fig. 3)

constant its thickness is gradually increasing. It will also be noted that the increase in heat exchanger capacity in the earlier CEGB stations made possible by using either eight or six exchangers, has now been replaced by the use of much larger but a reduced number of units. Some of these recent heat exchangers are almost the same thickness as the reactor pressure vessels and thus to some extent pose similar manufacturing problems.

The trend of using thicker low carbon steel for both reactor vessel and heat exchangers (apart from Sizewell) has led to a search for more rapid welding methods and in particular for the application of these methods on site as well as at works. A number of automatic welding processes have useful potential in this respect, but it is first pertinent to review the methods of construction so far used for both reactor vessels and heat exchangers in order to appreciate their full significance.

REACTOR VESSEL CONSTRUCTION

The eight reactor vessels of the Calder Hall and Chapelcross stations were all fabricated from individual panels, manually welded *in situ* using rutile type E.317 electrodes. The fact that 1700 ft of welded seam in 2 in thick steel is contained in each of these vessels suggests that automatic welding, in part at least, could have been employed (*1*). However, at the time of construction positional automatic welding was not sufficiently well developed to place confidence in the consistency of quality to be expected and downhand applications on sub-assemblies used in the works were restricted because of the site lifting capacity available. The same general practice of manual welding was adopted for the two reactor vessels at Berkeley, but low hydrogen electrodes of the E.614 type were used in view of the 3 in thickness involved. Again the percentage of automatic welding used in the works was restricted by the maximum lift and thus a

TABLE I *Plate thickness and size of the pressure vessels and steam raising units of UK gas-cooled graphite moderated reactors*

STATION	ELECTRICAL OUTPUT, MW	WORKING PRESSURE, lbf/in²g	REACTOR VESSEL DATA					STEAM RAISING UNIT DATA			
			No./ station	Type	Diameter, ft in	Height, ft	Thickness, in	Number/ reactor	Diameter, ft in	Height, ft in	Thickness, in
Calder Hall	150	100	4	Cylinder	37	70	2	4	17 3	77 4	1 7/8
Chapelcross	150	100	4	,,	37	70	2	4	17 3	77 4	1 7/8
Berkeley	275	125	2	,,	50	80	3	8	17 6	70	1 1/8
Bradwell	300	130	2	Sphere	66 9	—	3 and 4	6	19	82	1 7/8
Hunterston	330	150	2	,,	70	—	2 7/8	8	19 6	73 6	1 7/8 to 2 1/8
Hinkley Point	500	185	2	,,	67	—	3	6	21 6	90 4	1 7/8 to 2 1/8
Trawsfynydd	500	240	2	,,	61	—	3 1/8	6	18	116	2 1/2
Dungeness	550	270	2	,,	62 6	—	4	4	23 6	75	2 15/16 to 3 7/8
Sizewell	580	265	2	,,	63 6	—	4 1/8	4	22 6	91 6	2 1/4 (low alloy steel)

considerable amount of manual welding was necessary.

In all the other stations greater lifting capacity is available so that some 35% of the total footage is now done at works automatically. On the Trawsfynydd reactor, certain of the circumferential seams have been automatically welded *in situ* in addition to the above, thus from the Calder Hall programme in which no automatic welding is featured, we have now reached the stage where approximately 50% of the reactor seams have been automatically produced. There seems no reason why this figure cannot be increased further.

HEAT EXCHANGER FABRICATION

The heat exchanger has always been more suitable for automatic welding than the reactor vessel, because of its size and shape. The most common method of construction has been to fabricate shell strakes at the works and assemble on site in a suitably equipped workshop. In certain cases it has even been possible to completely works fabricate the vessels and transport the completed units by sea (*2*, *3*).

The percentage of automatic welding, therefore, is much greater than on the reactor vessel and this of course will always be so because of a certain amount of overhead welding being required on erection of the reactor vessels.

PROPERTIES OF AVAILABLE PROCESSES

There are three welding processes which can be applied to both reactor vessel and heat exchanger fabrication with advantage, whilst at the same time maintaining the high quality of weld which has been a feature of these containment vessels. It has already been indicated that 50% of the welded seams can be done by automatic methods but it is of interest to see what time can be saved dependent on the particular process employed. Table 2 gives such a comparison between manual metal arc, submerged arc in both the flat and horizontal positions and finally electroslag done in the vertical. Of necessity the figures quoted for manual methods are shown with wide variations since they depend to a great extent on the welding position and joint design. For submerged arc welding it has been assumed that a minimum run of 10 ft is possible and all the times exclude that required for plate preparation and setting up. Allowances have been made for inter run cleaning and back chipping where necessary.

Other processes which might be employed are the carbon dioxide shielded semi-automatic methods in which trouble from slag inclusions is virtually eliminated, and roughly three times the welding speed of manual metal arc is possible. Before any system can be used with confidence a number of conditions must be satisfied. These include the following:

(*a*) Are the weld metal properties equally satisfactory to what has been obtained from manual methods?
(*b*) Can radiographic soundness be equally well assured?
(*c*) What background of experience is there to draw on from their application on non-radiographic containments

An excellent review of all the relatively new welding processes has been recently given by Vernon (*4*) and thus some indication of their potentialities on a production basis is available. However, although it may take some time to answer all the above questions satisfactorily, weld metal properties can be fairly readily assessed.

In this respect it is of prime importance to consider the impact strength resulting from the use of automatic systems, The importance of good impact strength both during construction and subsequent service needs no stressing in this article. Likewise it is well known that particular care must be taken with the reactor vessel since the exposure to irradiation during its lifetime causes the transition temperature for ductile to brittle fracture to increase by as much as 100°C or more. With the heat exchanger not as much importance need be attached to impact strength, since no irradiation damage will occur, and better control during manufacture is possible since *in situ* welding on the actual site is eliminated.

TABLE 2 *Welding time in h/ft for Class 1 welds*

PLATE THICKNESS, in	MANUAL METAL-ARC (ALL POSITIONS), h	SUBMERGED ARC (DOWNHAND), h	SUBMERGED ARC '3 o'clock' (HORIZONTAL), h	ELECTROSLAG (VERTICAL), h
3	24/36	5	8	½
4	30/48	8	14	½

Impact strength of weld metal usually decreases as the weld structure increases in grain size. This of course tends to restrict the application of automatic systems since a useful increase in welding speed must be obtained whilst controlling weld pool size. Acceptance levels, based on Charpy V notch tests are indicated in Fig. 4, together with typical curves for weld metals deposited by various automatic processes, before and after heat treatment in the case of electroslag.

It will be noted that all of the automatic systems give somewhat inferior impact strength to weld metal obtainable from manually deposited type E.614 electrodes. Apart from the electroslag method the other processes can be controlled by restricting individual weld pass size to give satisfactory impact strengths without requiring any additional heat treatment. Unfortunately the electroslag method gives very poor properties in the weld and heat affected zone unless a normalizing treatment is applied, and up to the present time has only been advanced for relatively small reactor subassemblies and the longitudinal seams of heat exchanger strakes which can be furnace normalized.

FUTURE APPLICATIONS

Electroslag welding

The considerable saving in weld time obtained by using electroslag makes it justifiable to look closer at its future in respect to reactor and heat exchanger construction, and in particular to the problem of improving the notch ductility of the welds.

Apart from impact strength, other mechanical properties of the weld after a normal stress relieving treatment of 600/650°C are satisfactory.

Impact strength can be improved appreciably by normalizing, but the accurate control necessary suggests that it must be done on works premises having large furnaces. If this were the only method the process would lose a lot of its appeal since furnace heat treatment is expensive, particularly if support must be given to the various components against distortion. The development of localized methods of heat treatment would thus be handsomely rewarded.

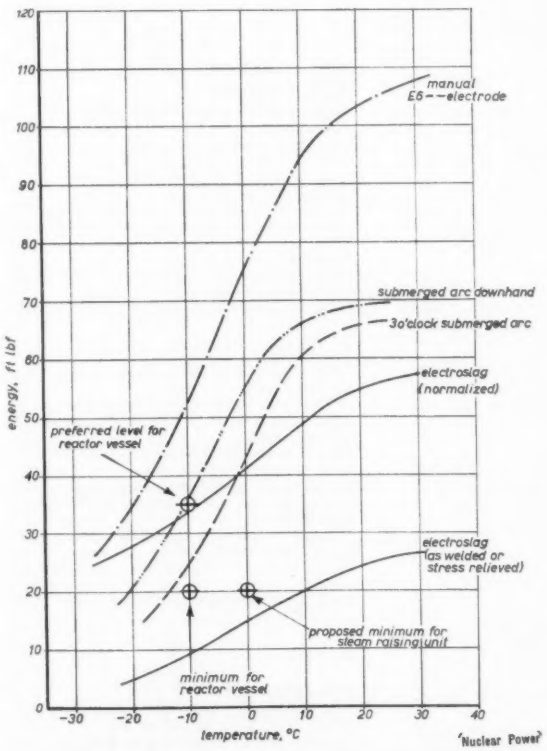
There are arguments advanced against localized stress relief on the grounds that undue stress is placed on adjacent welds or areas of stress concentration. Likewise it is possible that objections will be raised regarding a local normalizing procedure until adequate proof of its reliability is provided. There is no doubt that satisfactory conditions can be established by suitable control of temperature gradients in areas of concern, and thus provide the freedom of application essential to the increased use of the process.

From an examination of results obtained on a variety of

electroslag welds it is interesting to observe that the impact strength of the weld metal is significantly affected by the quality of the parent steel being welded without any change of welding wire being made. Thus if an aluminium-refined steel is welded, higher impact strength is obtained than would be possible with a silicon-killed steel without aluminium addition. Further improvement is claimed by one manufacturer by the use of a composite wire containing flux and deoxidizers (*5*). Whilst in general the centre of the weld has the worst properties the heat affected zone of the parent metal is relatively poor also. It would thus appear that if weld metal properties can be improved by making available new welding wires, the need for special post weld treatment can be reduced to a minimum by the selection of parent steel of high quality improving the heat affected zone.

The above considerations might have easier acceptance in heat exchanger construction where although longitudinal seams are electroslag welded at the moment, circumferentials are not as yet contemplated because of localized normalizing not being available, furnace capacity restricted to individual strakes and less incentive to apply it because submerged-arc methods are already in use. Thus if a guarantee of impact strength above 20 ft lbf at 0°C could be assured without a normalizing treatment, circumferential welds might also be undertaken in spite of the practical difficulties involved (*6*).

Regarding radiographic soundness, the electroslag method gives particularly good welds and when defects do occur they are gross and readily identifiable. The relatively small amount of repair which seems likely is fortunate since it must be done by manual methods which will take as long, or longer, than the whole of the original seam. It is a further comfort to know that distortion is extremely small and that weld cracking is a rather remote hazard in view of the wide variations from optimum that can be tolerated before its onset.



Acceptance levels for impact strength of weld metal with typical curves for weld metal deposited by various processes (Fig. 4)

'3 o'clock' welding

Other automatic processes have much greater freedom of application and have been extensively used on sub-assemblies for both reactor vessels and heat exchangers for several years. However, the increased use of these processes *in situ* on the reactor has only recently been possible with the introduction of '3 o'clock' welding. All that is entailed is a tractor type carriage traversing the seam to be welded at a controlled speed carrying either a submerged arc, continuous coil electrode or a CO_2 shielded metal-arc welding head.

At first sight it would appear that only the equatorial seam of the reactor sphere is amenable to the technique, particularly so for submerged arc where flux retention is important. However, if it is arranged so that the major portion of the weld preparation is on the inside of the lower hemisphere and the outside of the upper hemisphere, the technique could be applied to all the circumferential seams of the sphere.

It would of course be necessary to weld the minor portion of the preparation manually, back chipping and sealing as required. As has already been mentioned, control of individual weld run size produces weld metal of acceptable impact properties and it is the use of this method on three seams which has enabled the Trawsfynydd reactor shell to embody 50% of automatic welding.

Whether submerged-arc welding is the best process to apply with the technique is debatable since the CO_2 shielded metal arc appears to offer advantage since it produces a minimum of slag with consequent freedom from such inclusions. Welding speed should be similar and further advantage might be claimed since there are doubts expressed with submerged arc on the difficulty of maintaining correct electrode position when hidden under a burden of flux and that a departure from optimum conditions makes slag inclusion more than likely. It would be most instructive to apply CO_2 welding on steel of say 3 in thickness to make accurate comparison of both welding speed and consistency of weld quality on radiographic examination.

FINAL THOUGHTS

Irrespective of the process used and the proof by weld procedure tests that the proposed technique is satisfactory fears have been expressed that a fair footage of defective weld can be made before the trouble is brought to light. This point, whilst dismissed lightly by many, indicates the inherent desire of individuals to resist change even when faced with growing proof that equally satisfactory results are possible with automatic methods.

It rests with equipment manufacturers to lead the way in continued development of techniques and materials, and for industry in general and inspecting authorities in particu'ar to give sympathetic consideration to their use if the production of power from nuclear reactors is to continue its advance.

Acknowledgments

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This Review, prepared from answers to a 'Nuclear Power' questionnaire, gives an up to date guide to processes and equipment available in the United Kingdom

Welding and non-destructive testing equipment survey

Part 1. Welding and cutting processes

METAL ARC
covered electrode (manual and automatic)

AEI Heating and Welding Dept
500 A, 1000 A automatic equipment.
Arc Manufacturing Co. Ltd
British Oxygen Co. Ltd
Complete range of covered electrodes for manual welding, also the 'Fusarc,' 'Fusarc/CO_2' and 'Fusemelt' automatic processes.
English Electric Co. Ltd
Single and double operator a.c. portable, single operator a.c./d.c. portable, single operator d.c., multi-operator a.c. (3–12 operators). All this equipment for manual welding.
Esab Ltd
General Electric Co. Ltd
Interlas Ltd (distributors for Miller Electric Mfg Co. Inc.)
a.c., d.c. and a.c./d.c. for both metallic arc and argon arc processes.
Lincoln Electric Co. Ltd
Messer Industrial Engineering Ltd
Murex Welding Processes Ltd
'Muramatic' automatic machine.
Petbow Ltd
Manual.
Portable Welders Ltd
'Fararc' series III toroidal welder, 60–300 A, 90 lb weight, 14 in cube.
Research and Control Instruments Ltd
Rockweld Ltd
Triangle Products Ltd
Weldcraft Ltd (member of the G. D. Peters Group)
A. S. Young & Co. Ltd

GAS SHIELDED METAL ARC
tungsten (argon) arc (T.I.G.)

AEI Ltd Heating and Welding Dept
Manual and automatic machines.
Arc Manufacturing Co. Ltd
Special rectifier, remotely controlled with crater filling device, high frequency. Capacities of 100 and 150 A.
British Oxygen Co. Ltd
a.c. and d.c. 'Argonarc' equipment and accessories.
British Federal Welder & Machine Co. Ltd
Specially designed machines with automatic fixtures.
F. Hirschman Ltd
Normal sizes: 30, 150, 250 and 400 A. Built as a.c. or as rectifier plants. Available as fully automatic plants; single press button release of full cycle of operation, with built-in control of arc length, filler wire feed, traverse or rotation, ionizer, gas, etc. Automatic machine for argon arc welding of aluminium fuel cans supplied to UKAEA.
Interlas Ltd
a.c, d.c. and a.c./d.c. Miller machines.
Palmer Aero Products Ltd
Automatic machinery for orbital welding of tube assemblies. Control circuit designed and machine built by F. Hirschman Ltd.
Rowen-Arc (Division of Rubery Owen & Co. Ltd)
Sciaky Electric Welding Machines Ltd
Special purpose T.I.F. fusion welding machines equipped with Sciaky 'Zero Error' arc control device; particularly suitable for welding light alloy vessels, etc.
Saturn Industrial Gases Ltd
Mark 1A surge injector for use with proprietary transformer up to 300 A. Mark II surge injector (a.c.) with own power source, either 30–300 or 60–600 A. All with torch and argon regulator. 'Seirion' up to 300 A d.c. for use with proprietary d.c. power source—generator or rectifier set. (Initiates arc without need of contact between electrode and workpiece.)

GAS SHIELDED METAL ARC
atomic hydrogen

AEI Ltd Heating and Welding Dept
Interlas Ltd
Miller machine.

GAS SHIELDED METAL ARC
inert gas metal arc (M.I.G.) (manual and automatic)

AEI Ltd Heating and Welding Dept
Manual and automatic.
British Oxygen Co. Ltd
Semi and fully automatic 'Sigma' equipment for argon and argon/oxygen welding.
F. Hirschman Ltd
Rectifier plants with infinitely variable setting of voltage, slope, short circuit current and response.
Interlas Ltd
Slope-controlled Miller machine
Rowen-Arc (Division of Rubery Owen & Co. Ltd)

GAS SHIELDED METAL ARC
CO_2 shielded

AEI Ltd Heating and Welding Dept
Automatic.
Arc Manufacturing Co. Ltd
600 A. Constant potential rectifier using wire sizes $\frac{3}{64}$ in to $\frac{1}{8}$ in in $\frac{1}{64}$ in increments.
British Oxygen Co. Ltd
Semi and fully automatic equipment for spray or dip transfer techniques using CO_2 or argon/CO_2.
Esab Ltd
Esab A7 machines fully and semi-automatic.
F. Hirschman Ltd
Rectifier plants with infinitely variable setting of voltage, slope, short circuit current and response.
Interlas Ltd
Slope controlled Miller machine.
Lincoln Electric Co. Ltd
Sprite CO_2 semi-automatic welding equipment. Lincolnweld Type B.30 fully automatic CO_2 welding head.
Messer Industrial Engineering Ltd
Semi-automatic equipment.
Research & Control Instruments Ltd
Philips manual and automatic equipment.
Rockweld Ltd
'Comet' mobile semi-automatic; 'Duomatic' twin fillet welder; 'Circomatic' girth seam welder; 'Vertomat' vertical plate welder.
Rowen-Arc (Division of Rubery Owen & Co. Ltd)

SUBMERGED ARC

AEI Ltd Heating and Welding Dept
500 A, 1000 A automatic machines.
British Federal Welder & Machine Co. Ltd
With special automatic features.
British Oxygen Co. Ltd
Full range of automatic equipment.

Lincoln Electric Co. Ltd
Lincolnweld and manual Lincolnweld, fully and semi-automatic units.
Murex Welding Processes Ltd
' Muramatic ' welding head. Can be used with a.c. or d.c., in the horizontal/vertical position or downhand. Two welding heads can be mounted in a self-propelled carriage for twin-fillet welding.
Rockweld Ltd
' Autopak ' fixed and travelling heads.
Esab Ltd
Esab A 6 series fully automatic, including twin-fillet welders.

ELECTROSLAG

British Oxygen Co. Ltd
' Subarc ' process.
Esab Ltd
Esab ES 3 for up to 20 in plate; Esab ES 5 portable for up to 3⅛ in plate.
Rockweld Ltd
' Vertomatic ' vertical slab and thick plate welder.

RESISTANCE WELDING
spot

AEI Ltd Heating and Welding Dept
All types and sizes, manual and automatic.
AI Electric Welding Machines Ltd
ARO Machinery Co. Ltd
Wide range of portable, bench and pedestal equipment.
D. S. Baddeley Engineering Co. Ltd
Various types.
British Federal Welder & Machine Co. Ltd
All types from 1 kVA to over 800 kVA, single point and multi head.
Burnley Aircraft Products Ltd
Conos Spot Welding Equipment
Portable machines for welding austenitic and mild steel sheet from 0·002 in to 16 s.w.g. on to any thickness. Also long throat reach two-sided spot welders.
Fuller Electric Ltd
Complete range of Aseaweld machines.
Hirst Electronic Ltd
Holden & Hunt Ltd
Pedal, air and motor operated.
Meritus (Barnet) Ltd
Complete range of standard types from 3 to 60 kVA.
Messer Industrial Engineering Ltd
New Process Welders Ltd
Pedal, air or hydraulic in sizes from 1 to 250 kVA. Also portable guns.
Portable Welders Ltd
Range of portable spot welding guns; all with transformer in gun for maintenance and production use. Can be pedestal mounted with hand, foot or pneumatic operation, 4·8 to 24 kVA.
Sciaky Electric Welding Machines Ltd
Single phase and three phase machines light alloy machines for fabrication of magnox fuel elements. Standard machines from 2 to 1000 kVA.
Siemens-Schuckert (Great Britain) Ltd
1 to 100 kVA pedal and air-operated.
Triangle Products Ltd

RESISTANCE WELDING
seam

AEI Ltd Heating and Welding Dept
Range of all types and sizes, manual and automatic.
British Federal Welder & Machine Co. Ltd
All types including bench and pedestal machines.
Fuller Electric Ltd
Complete range of Aseaweld machines.
Messer Industrial Engineering Ltd
Meritus (Barnet) Ltd
Special seam welding head fits the ' Meritus ' standard spot welding machine.
New Process Welders Ltd
Pedal and air operated. Longitudinal, circumferential, universal, moving carriage. Also tube weld units resistance or high frequency. 10 to 250 kVA.
Siemens-Schuckert (Great Britain) Ltd
25 to 100 kVA pedal and air operated.

RESISTANCE WELDING
projection

AEI Ltd Heating and Welding Dept
Manual and automatic.
D. S. Baddeley Engineering Co. Ltd.
Range of machines from 50 to 400 kVA.
British Federal Welder & Machine Co. Ltd.
All types including bench and pedestal machines, multi-head, etc., single phase or three phase.
Fuller Electric Ltd
Range of Aseaweld machines.
Hirst Electronic Ltd
Holden & Hunt Ltd
Messer Industrial Engineering Ltd
New Process Welders Ltd.
Air or hydraulic, single or three phase, 10 to 500 kVA.
Sciaky Electric Welding Machines Ltd
Special three phase machines used for attaching thermal fins to superheater tubes.
Siemens-Schuckert (Great Britain) Ltd
Up to 150 kVA.

RESISTANCE WELDING
butt

AEI Ltd Heating and Welding Dept
Manual and automatic.
British Federal Welder & Machine Co. Ltd
From 2 to 50 kVA or greater, pedestal type and including butt percussion.
Fuller Electric Ltd
Aseaweld machine.
Messer Industrial Engineering Ltd
Meritus (Barnet) Ltd
Wire butt welding machines, and special butt welding attachments for the spot welding machine.
New Process Welders Ltd
Hand, pedal, motor or air operated; 2 to 25 kVA.

RESISTANCE WELDING
flash

AEI Ltd Heating and Welding Dept
Manual and automatic flash butt welders
AI Electric Welding Machines Ltd
Wide range of automatic flash butt welding equipment. AI type AF/1 welder supplied to the UKAEA for welding zirconium tubes.
British Federal Welder & Machine Co. Ltd
All types from 12 to 1500 kVA or greater including cam, air hydraulic and full hydraulic drive systems.
Fuller Electric Ltd
Automatic Aseaweld machines.
Messer Industrial Engineering Ltd
Holden & Hunt Ltd
Manual and automatic flash butt welders.
New Process Welders Ltd
Hand, air, motor or hydraulic operated, 12 to 250 kVA.
Sciaky Electric Welding Machines Ltd
Machines for flash welding boiler tubes, rated up to 400 kVA for tubes up to 6 in dia.

STUD WELDING

Crompton Parkinson Ltd
Research & Control Instruments Ltd
Philips stud welding equipment.

SPECIAL PROCESSES
electron beam

Edwards High Vacuum Ltd
' Speedivac ' model EB2
Sciaky Electric Welding Machines Ltd
Wild-Barfield Electric Furnaces Ltd
Two types made under licence from NRC Equipment Corporation.

capacitance discharge

Kerry's (Ultrasonics) Ltd
Portable, bench, multiple and automatic stud welders. (Kerry's also are developing seam and spot welders using ultrasonics).
Spembly Ltd
Fine wire welding, for thermocouples, thermopiles and heaters. Flash butt and spot welding, in inert gas atmosphere.

Cold Pressure Welding

General Electric Co. Ltd
User licences available. Development work for licencees undertaken.

friction welding

British Federal Welder & Machine Co. Ltd
Specially designed machines available for individual applications.
Degenhardt & Co. Ltd
Carl Zeiss electron beam welder.

radio frequency

Redifon Ltd
Range of machines for welding plastics. Also guns supplied for welding plastics in a similar manner to conventional metal welding (details from subsidiary company Rediweld Ltd).

GAS WELDING AND CUTTING

D. S. Baddeley Engineering Co. Ltd
Range of hand welding, cutting, gouging, brazing equipment.
British Industrial Gases Ltd
' Cub ' profiling machine. ' Cutomation ' system for machine profiling with oxypropane fuel.
British Oxygen Co. Ltd
Range of hand cutting equipment, plate edge preparation machines, cutting machines, portable cutting machines, profile cutting machines, tube profile cutting machines; for oxyfuel gas and air fuel gas.
Centrajet Ltd
Oxygen hand cutters.
Esab Ltd
All sizes of oxygen profiling machines from OK Telerex 1-100 electronically controlled to OK Cadet electro hand tool. ' Kinox ' powder cutting equipment.
General Precision Systems Ltd
Automatic flame-cutting tube profiler.
Hancock & Co. (Engineers) Ltd
Wide range of oxygen cutting and profiling machines, flame planing, edge preparation, tube profiling and tube cutting machines.
Kimbell Machine Tools Ltd
Schichau-Monopol and Schichau-Quadruplex electronically controlled automatic flame cutting machines.
Lincoln Electric Co. Ltd
Arcair cutting and gouging torches, Arcair copper coated carbons. (Not a gas process: metal melted by arc and blown away by compressed air).
Messer Industrial Engineering Ltd
All types of hand welding and cutting equipment. Profile cutting machines from small hand machines to electronically controlled machines with a work area of 2×12×90 in.
C. S. Milne & Co. Ltd
Hand and machine cutting equipment.
Pollock & Peel Ltd
Wide range of hand welding and cutting equipment.
Saturn Industrial Gases Ltd
Cutters Mark III & IV and new lightweight ' Scimitar ' cutter, for either oxyacetylene or oxypropane.
Suffolk Iron Foundry (1920) Ltd
Hand welding and cutting equipment. SIF75 Cutomatic precision oxy-flame machine with magnetic tracer head or free-hand drawing tracer head. SIF Combi dual purpose machine for either profiling or straight line and circle cutting. SIF Colibri motor driven machine for straight line or circle cutting.
Weldcraft Ltd (member of G. D. Peters Group)
Range of gas welding and cutting equipment.
A. S. Young & Co. Ltd
Oxy-acetylene welding and cutting equipment.

POWER SOURCES
transformers

AEI Ltd Heating and Welding Dept
250/330 A and 350/450 A a.c. single operator Thermac. 57, 90, 128 and 160 kVA a.c. multi-operator.
Arc Manufacturing Co. Ltd
Monta 15–200 A air-cooled, Modula 30–250 A oil-cooled, Media 30–300 A air and oil-cooled, Masta 40–440 A oil-cooled.
Aveley Electric Ltd
Toroidal transformers up to 250 A.
D. S. Baddeley Engineering Co. Ltd
110 A Minor. Models B & 2B 160 & 300 A. Model C 250 A. Model DR 800 300 A for two operators 600 A for single operator.

Part 2. Supplies and accessories

British Federal Welder and Machine Co. Ltd
British Oxygen Co. Ltd
' Quasi-Arc ' sizes from 200–1000 A, for use with ' Fusarc/CO_2 ' ' Unionmelt ' and ' Sigma ' processes.
English Electric Co. Ltd
Single operator a.c. range: LWC200 30–200 A, LWC300 34–315 A, LWC450 59–450 A, LWC600 116–625 A. LWC2/300 315 A for two operators or 630 A for one. LWM standard multi-operator transformer, four sizes—3, 6, 9 or 12 operators, 350 A each, 3 phase 50 cycle supply. LWMC composite multi-operator transformer four sizes 3, 6, 9, or 12 operators. LWR current regulators for multi-operator transformers, 210, 350, 450 & 600 A sizes. ' Shipyard ' models available ensuring correct welding currents when long welding leads used.
Esab Ltd
Esab GB range 150 to 500 A.
Fuller Electric Ltd
Up to 600 A.
General Electric Co. Ltd
Single operator range: OT1A 380-440V, 20-425A, OT1B, 190-550V, 20-425A, OT2 380-550V, 120-700A. Multi operator plant: M6 380-440V, 95kVA, 350A (6 chokes), 450A (3 chokes), M9 380-440V, 128kVA, 350A (9 chokes), 450A (6 chokes). Ancillary equipment.
Haddon Transformers Ltd
F. Hirschman Ltd
200 A with infinitely variable current setting.
Hirst Electronic Ltd
Transformers and saturable reactors
Interlas Ltd
Unitor and Miller.
Lincoln Electric Co. Ltd
Single and multi-operator a.c. transformers.
Max-Arc Ltd
Complete range of air and oil-cooled sets, single and double operator up to 600 A.
Meritus (Barnet) Ltd
Supplied to specification only.
Murex Welding Processes Ltd
Single operator air-cooled 210 A. Single operator oil-cooled 250–450 A. Double operator oil-cooled 250-375 A. Multi-operator oil-cooled up to 24 operators currents up to 600 A depending on capacity.
Oerlikon Electrodes (GB) Ltd
Research & Control Instruments Ltd
Philips 400 A oil-cooled and 60, 175, 350 A air-cooled.
Rockweld Ltd
Single operator, 200, 300 and 400 A. Double operator 300/600 A (also used with Autopak submerged arc plant. Multi-operator sets 6, 9 and 12 operators at 350, 450 and 600 A.)
Triangle Products Ltd
Weldcraft Ltd (member of the G. D. Peters Group)
Lion series.
A. S. Young & Co. Ltd
Up to 300 A.

POWER SOURCES
rectifiers

AEI Ltd Heating and Welding Dept
400 A transformer/rectifier set.
Arc Manufacturing Co. Ltd
100 and 150 A argon-arc rectifiers.
British Oxygen Co. Ltd
Sizes from 200–1200 A, drooping characteristics and slope control.
Crompton Parkinson Ltd
Transformer/rectifiers for stud and arc welding.
English Electric Co. Ltd
LWD350 oil-cooled infinitely variable output over the range 25–350 A d.c., LWAD300 portable provides d.c. or a.c. at turn of a switch range a.c. 34–315 A, d.c. 27–250 A, similar models LWAD450 current range a.c. 59–450 A, d.c. 47–360 A, LWAD600 current range a.c. 116–625 A, d.c. 95–520 A, LWCP500 constant power pack for automatic welding uses heavy duty selenium rectifiers and with a dynamic reactor is suitable for dip transfer process, output 500 A d.c.
F. Hirschman Ltd
30, 150, 250 and 400 A plants.
Interlas Ltd
Over 100 Miller models.
Lincoln Electric Co. Ltd
Arcmaker d.c. silicon rectifiers.
Meritus (Barnet) Ltd
Supplied to specification only.
Murex Welding Processes Ltd
150 and 350 A d.c. sets.
Research & Control Instruments Ltd
Two duel-purpose plants for rectified a.c. or d.c., range a.c. 40–240 A d.c. 10–80 A and a.c. 60–300 A d.c. 25–140 A.
Rowen-Arc (Division of Rubery Owen & Co. Ltd)
Silicon rectifier machines 400 A, range of silicon rectifiers for the Rowen-Arc arc-spot welders.

POWER SOURCES
a.c. and d.c. motor generators

AEI Ltd Heating and Welding Dept
300/400 A d.c. ' Paradyne '.
Arc Manufacturing Co. Ltd
a.c./d.c., single and double operator up to 800 A.
British Oxygen Co. Ltd
Sizes from 225 to 750 A.
Esab Ltd
Esab KB series from 150 to 1000 A.
Fuller Electric Ltd
Aseaweld set 30–250 A.
Lancashire Dynamo and Crypto Ltd
400 A a.c./d.c. welding set.
Lincoln Electric Co. Ltd
Lincoln motor generators in sizes providing from 150 to 900 A continuously.
Max-Arc Ltd
Single and double operator sets up to 600 A.
Murex Welding Processes Ltd
Range of equipment giving up to 900 A.
Petbow Ltd
Range of equipment giving up to 800 A double operator.
A. Reyrolle & Co. Ltd
175/425 A d.c. single operator
Rockweld Ltd
Single operator 175, 250, 300, 375 and 400 A. Double operator 300/600 A.
Weldcraft Ltd
Up to 300 A.

POWER SOURCES
petrol and diesel driven generators

AEI Ltd Heating and Welding Dept
200/300 A, 300/400 A d.c. engine driven.
Arc Manufacturing Co. Ltd
a.c./d.c., single and double operator up to 800 A.
D. S. Baddeley Engineering Co. Ltd
From 250 to 600 A.
British Oxygen Co. Ltd
Sizes from 200 to 600 A (petrol and diesel).
Esab Ltd
Esab/petter, 375 A output.
Interlas Ltd
Miller.
Lincoln Electric Co. Ltd
Supplied in a wide range of types providing 150-600 A continuous output, powered by Ford, Ruston, Perkins and other makes.
Max-Arc Ltd
Complete range of both petrol and diesel driven sets, single and double operator up to 600 A, including Port-el-Arc which incorporates the industrial Volkswagen engine.
Murex Welding Processes Ltd
250 A single operator petrol driven, single and double operator diesel driven sets up to 800 A output.
Petbow Ltd
Mobile and skid mounted range of diesel driven sets 300 to 800 A continuous duty.
A. Reyrolle & Co. Ltd
Single operator diesel-driven 175/425 A.
Rockweld Ltd
Mobile sets. Single operator Enmac diesel, Hobo diesel, Hobette petrol. Double operator diesel 300/600 A and 400/800 A.

GASES & GAS REGULATORS

AEI Ltd Heating and Welding Dept
Regulators for argon and atomic hydrogen.
D. S. Baddeley Engineering Co. Ltd
Gas regulators, valves, couplers and acetylene generators.
British Industrial Gases Ltd
Gas manifolds and regulators.
British Oxygen Co. Ltd
Atmospheric gases, fuel gases and special gas mixtures. Complete range of regulators for high and low inlet pressures and varying outlet pressures.
The Distillers Co. Ltd
Carbon dioxide.
Messer Industrial Engineering Ltd
Range of gas regulators.
C. S. Milne & Co. Ltd
Single and two-stage regulators, high pressure valves.
Saturn Industrial Gases Ltd
Oxygen, nitrogen, hydrogen and dissolved acetylene. Regulators for all gases.
Suffolk Iron Foundry (1920) Ltd
Gas regulators.
Weldcraft Ltd
Range of regulators for all gases. Acetylene generators and ' gasfluxing ' equipment.
A. S. Young & Co. Ltd
Pressure regulators.

ELECTRODES, WIRES, RODS

AEI Ltd Heating and Welding Dept
Tungsten electrodes, wide range of electrodes for mild, steel, high tensile steel, corrosion resisting, hard surfacing, cast iron, creep resisting. Metromatic fluxes and core wire for submerged arc welding. Bare and covered wire for automatic welding.
Arc Manufacturing Co. Ltd
All types and sizes of covered electrodes for mild and low alloy steels, hard facing, stainless steel, bronze, cast iron. All sizes of silicon-killed triple deoxidized wire for CO_2 welding.
British Oxygen Co. Ltd
Complete range of covered electrodes for manual welding mild steel, high-tensile steel, corrosion resisting steel, hard facing, non-ferrous metals. Thoriated and zirconiated tungsten electrodes for argonarc welding. Reeled and spooled wires for automatic and semi-automatic welding. Cut lengths for argonarc and gas welding. Range of continuous covered electrodes.
British Insulated Callender's Cables Ltd
' Bicaloy ' electrode tips for resistance welding.
Cooper & Turner Ltd
' Diadem ' range of electrodes for mild steel, low and high alloy steels, cast iron, hard facing.
Deloro Stellite Ltd
Hardfacing rods and powders.
English Electric Co. Ltd
Wide range of electrodes for all positions for, mild steel, stainless steels, creep-resisting steel, manganese steel, hard facing, cast iron, S.G. cast iron, grooving and gouging.
Esab Ltd
Wide range of OK electrodes for mild steel,

low alloy, medium alloy and high tensile steels, cast iron, hard facing, non-ferrous metals. OK Autrod wire.

Eutectic Welding Alloys Ltd
25 types from $\frac{1}{16}$ to $\frac{1}{4}$ in dia. for welding virtually all types of metals. 36 types of rods for gas torch welding. Both electrodes and rods for ' low heat input ' techniques.

Fuller Electric Ltd
Range of arc welding electrodes and flux coated filler rods.

Interlas Ltd
Tungsten electrodes.

Invicta Electrodes Ltd
Range of covered electrodes for mild steel, range of special steels and reinforcing. Copper coated mild steel rod for auto welding, $\frac{1}{16}$ to $\frac{1}{4}$ in dia.

Richard Johnson & Nephew Ltd
Welding wire supplied to electrode manufacturers.

Johnson, Matthey & Co. Ltd
Range of ' Mallory ' electrode materials for all resistance welding processes. Resistance welding electrodes supplied to customers' requirements. Range of seam welding wheels.

Lincoln Electric Co. Ltd
Full range of manual electrodes for mild steel, stainless and special steels, cast iron, non-ferrous metals and hard surfacing. Lincoln wires and fluxes for submerged arc welding, Lincoln type C3 wire for CO_2 welding. LECO No. 1 flux coated bronze welding rod for gas welding.

Morganite Carbon Ltd
Carbon and graphite electrodes.

Murex Welding Processes Ltd
Wire range of electrodes for iron and mild steel, medium high tensile steels, high tensile steels, creep-resisting steels, hard facing, stainless and heat-resisting steels, non-ferrous metals, cast iron. Continuous covered electrodes.

New Process Welders Ltd
Electrodes for spot, seam, projection and flash butt welders.

Oerlikon Electrodes (GB) Ltd
Wide range of all types for mild steel, stainless, cast iron, surfacing, creep-resisting, cutting, bronze.

Portable Welders Ltd
Full range of chrome copper electrodes for spot welding, arc welding electrodes for mild steel.

Research & Control Instruments Ltd
Range of Philips electrodes for mild steel, low alloy steels, creep-resisting steels, stainless steels, bronze and cast iron, cast iron, hard surfacing. CO_2 welding wire.

Rockweld Ltd
Range of electrodes for mild steel, special for mild steel, stainless steel, low alloy steel, hard surfacing, non-ferrous metals. Welding wire for submerged arc. Flux cored wire for CO_2 and electroslag welding.

Saturn Industrial Gases Ltd
Aluminium and bronze welding rods. Range of rods for oxy-acetylene welding. Range of rods and wires for inert gas arc welding of copper, aluminium, stainless steel and magnesium alloys.

Sciaky Electric Welding Machines Ltd
Range of electrodes for mild steels, heat-resisting steels, light alloys, non-ferrous metals.

Wall Colmonoy (Canada) Ltd
' Colmonoy ' hard facing and corrosion resisting alloys.

Weldcraft Ltd (Member of the G. D. Peters Group)
Range of gas welding rods.

A. S. Young & Co. Ltd
Range of gas welding rods.

POSITIONERS, JIGS, MANIPULATORS

AEI Ltd Heating and Welding Dept
Special purpose manipulators.

British Federal Welder & Machine Co. Ltd
Jigs.

F. Bode & Son Ltd
' Rotilting ' manually operated positioners up to 1-ton capacity. Conventional positioners up to 30 tons. Self-aligning rotators up to 1-ton capacity. Columns and booms, single and twin columns to suit requirements.

Baldwin Industrial Controls
Fluid power equipment for positioning welding equipment.

British Oxygen Co. Ltd
Manipulators, roller beds, ram-type welding booms (Quasi-Arc).

Courtburn Positioners Ltd
Welding positioners from 1 cwt to 5 tons capacity. Rotators 5 cwt to 60 tons capacity. Sheet clamping machines all sizes. Special purpose manipulators to customer requirements.

F. Hirschman Ltd
Longitudinal jigs and torch traversing gears, adjustable torch stands for circumferential welding.

Hancock & Co. (Engineers) Ltd
Automatic gas cutting machines can be converted to use with automatic welding heads.

Interlas Ltd
All types.

Lincoln Electric Co. Ltd
Columns and booms, rotators, manipulators, magnetic clamps and fully automatic positioning/welding installations.

James Neill & Co. (Sheffield) Ltd
Range of magnetic welding workholders.

Donald Ross & Partners Ltd (Murex Welding Processes Ltd)
Wide range of holding and positioning equipment. Load-balanced and self-balanced positioners, turning rolls, tilting beds, turntables, column and boom for ' Muramatic ' welding head, magnetic clamps.

Yates Plant Ltd (Baker Perkins Ltd)
Range of manipulators, welding columns and booms, rotators.

PRE- AND POST HEAT EQUIPMENT

British Oxygen Co. Ltd
Gas and induction heating equipment available, induction heaters 600 and 1000 A.

Electrothermal Engineering Ltd
' Flexible Furnace ' modular and custom-built units for temperatures up to 650 and 1000° C, for the heat treatment of workpieces of any shape and size; also up to 1500° C. Armoured heaters in various lengths for wind-on application, temperatures up to 800° C.

English Electric Co. Ltd
Thermees electrodes can be used for pre- and post-heating without additional equipment.

Lincoln Electric Co. Ltd
Motor generators for stress relieving and also induction heating rings for pre-and post-heat.

OPERATORS ACCESSORIES

AEI Ltd Heating and Welding Dept
Electrode holders, gloves, helmets, aprons, handshields, etc.

George Angus & Co. Ltd
Gloves, aprons, etc., in leather, rubber, p.v.c. Helmets, face shields, goggles.

Arc Manufacturing Co. Ltd
Extensive range of all accessories.

D. S. Baddeley Engineering Co. Ltd
Electrode holders, face shields, screens, goggles, respirators, etc.

British Oxygen Co. Ltd
Complete range of electrode holders, screens, etc.

Courtburn Positioners Ltd
Electrode holders, earth clamps, magnetic clamps, pipe clamps, eye shields, welding vices, etc.

English Electric Co. Ltd
Complete range of accessories.

Esab Ltd
Full range of accessories.

Fuller Electric Ltd
Electrode holders, helmets.

General Electric Co. Ltd
Safety type electrode holder.

Interlas Ltd
' Shortstub ' and ' terrier ' electrode holders, earth clamps, cable connectors, cable.

Lincoln Electric Co. Ltd
Full range of electrode holders, face shields, welding gloves and clothing, etc.

Cooper & Turner Ltd
Electrode holders, gloves, aprons, helmets, hand screens, and clamps.

Max-Arc Ltd
Complete range of electrode holders, gloves, aprons, etc.

Murex Welding Processes Ltd
Wide range of electrode holders, cables and accessories, screens and tools, helmets and shields, goggles, protective clothing, etc.

Oerlikon Electrodes (GB) Ltd
Electrode holders, cable, connectors, earth clamps, tools, glasses, gloves, aprons, screens, etc.

Petbow Ltd
Electrode holders, helmets, shields, goggles, clothing, etc.

Portable Welders Ltd
Usual range of accessories supplied with all arc welders.

Research & Control Instruments Ltd
Electrode holders, screens and shields, clamps, cable, clothing, etc.

Rockweld Ltd
Electrode holders, shields, helmets, cable, clamps, leather goods, tools, oxyarc equipment, etc.

Saturn Industrial Gases Ltd
Comprehensive range.

Suffolk Iron Foundry (1920) Ltd
Goggles.

Weldcraft Ltd (Member of the G. D. Peters Group)
Range of accessories for arc welding and gas welding.

A. S. Young & Co. Ltd
Electrode holders, goggles, torch igniter, etc.

CLEANING EQUIPMENT

British Oxygen Co. Ltd
Flame cleaning equipment.

Kerry's (Ultrasonics) Ltd
Ultrasonic cleaning equipment from 1 litre to 80 gal. capacity.

Industrial Descaling Tools Ltd
' Lark ' air motor tube cleaner.

Messer Industrial Engineering Ltd
Hand deseaming torches.

Vacu-Blast Ltd
Range of equipment for cleaning plate before oxy-acetylene cutting, preparation for all types of resistance welding, ultrasonic testing, cleaning welding wire. Wide range of equipment with closed circuit system. Machines also used for weld deslagging and final cleaning.

CONTROL EQUIPMENT

ACM Electronics
Two sizes of spot welding timers.

AEI Ltd Electronic Apparatus Division
Range of thyratron timers, ignitron contactors and other timing and weld control equipment for all types of resistance welding. Electronic tracing head for flame cutters.

ARO Machinery Co. Ltd
Spot welding timers

British Federal Welder & Machine Co. Ltd
Electronic control gear for resistance welding.

British Oxygen Co. Ltd
Timer and contactor units for spot welders.

Crompton Parkinson Ltd
Controllers for stud welding.

Esab Ltd
Remote current control.

Fuller Electric Ltd
Resistance welding controllers and timers.

F. Hirschman Ltd
Automatic arc length control for profile welding.

Hirst Electronic Ltd
Timing controllers.

Lancashire Dynamo Electronic Products Ltd (A member of the Metal Industries Group)
Electronic contactors, spot welding and other resistance welding process timers, stepless heat control and automatic current control.

Lincoln Electric Co. Ltd
Remote control equipment for CO_2 welding.

New Process Welders Ltd
For resistance welding equipment.

Portable Welders Ltd
Resistance welding timers.

Research & Control Instruments Ltd
Philips control contactors and current control box.

Saturn Industrial Gases Ltd
Argon-arc surge injector.

Sciaky Electric Welding Machines Ltd
Timers, fully synchronous spot and seam welder panels, phase shift units, cycle recorders, ' three-phase ' system of resistance welding control.

Part 3. Nondestructive testing equipment

X-RAY

AEI Ltd Instrumentation Division
Baldwin Industrial Controls
X-ray dosemeters.
Marconi Instruments Ltd
Complete range of equipments with outputs ranging from 50 to 300 kV.
Pantak Ltd
Mobile and laboratory X-ray equipment from 50 to 500 kV, supplied to many nuclear power projects.
Research & Control Instruments Ltd
'Macro 50' low filtration unit, Muller portable units 100, 140, 200, 260 and 300 kV, Muller MG 150/300 constant potential unit.
Solus-Schall Ltd
Portable X-ray units, oil immersed for 120, 160, 200, 260 and 300 kV, gas filled 180 kV. The high voltage transformer and X-ray tube are in a single steel cylinder filled with oil or gas.
Watson & Sons (Electro-Medical) Ltd Industrial Division
'Andrex' portable X-ray units, 140, 160, 160/360°, 200, 260 kV. 160 kV/360° units used at Hinkley Point and Trawsfynydd. Xeroradiography equipment for rapid X-ray examination.

GAMMA RAY

AEI Ltd Instrumentation Division
Arc Manufacturing Co. Ltd
Single and double source, iridium and cobalt.
Baldwin Industrial Controls
Industrial dosemeters, doserate meters, etc.
Gamma-Rays Ltd
Gamma radiographic equipment.
Pantak Ltd
Iridium, caesium and cobalt containers.
Pantatron Ltd
Wide range of gamma ray equipment.
Solus-Schall Ltd
Range of isotope containers for all types of gamma radiography; personnel dosemeter.
Watson & Sons (Electro-Medical) Ltd Industrial Division
Isotope containers, Co-60 and Ir-192 from Atomic Energy of Canada Ltd.

PARTICLE ACCELERATORS

AEI Ltd Instrumentation Division
Pantak Ltd
18 MeV betatron.
Research & Control Instruments Ltd
Mullard 4-3 MeV linear accelerator.
Watson & Sons (Electro-Medical) Ltd Industrial Division
Brown-Boveri 31 MeV betatron for examining steels up to 20 in thick.

ULTRASONIC

Aveley Electric Ltd
Kretz equipment.
Research & Control Instruments Ltd
Sonatest flaw detector TE/2.
Smiths Industrial Division
Range of Kelvin Hughes flaw detectors, also Curtiss-Wright Immerscope.
Solus-Schall Ltd
Three types of detector supplied together with accessories.

MAGNETIC

AEI Ltd Instrumentation Division
Aveley Electric Ltd
Labimex-Werner apparatus.
Esab Ltd
Range of a.c. and d.c. machines.
New Process Welders Ltd
Small a.c. or d.c. portable machines.
Research & Control Instruments Ltd
Portamag 850 portable detector.
Solus-Schall Ltd
Range of magnetic crack detectors and magnetizing units, also magnetic particle inks.

PENETRANTS

Brent Chemical Products Ltd
Large range of 'Ardrox' penetrants.
Solus-Schall Ltd
Non-magnetic fluorescent penetrants, processing equipment, UV lamp.

Company Addresses

ACM Electronics Ltd
61 Osborne Road, Acton, London W3 (Acorn 6931)
AEI Ltd Electronic Apparatus Division
New Parks Boulevard, Leicester (Glenfield 531)
AEI Ltd Transformer Division Heating & Welding Dept
Trafford Park Manchester 17, (Trafford Park 2431)
AEI Ltd Instrumentation Division
Trafford Park, Manchester 17, (Trafford Park 2431)
AI Electric Welding Machines Ltd
Rose Street, Inverness (Inverness 33061)
George Angus & Co. Ltd
Angus House, 152-158 Westgate Road, Newcastle upon Tyne 1, PO Box 139 (Newcastle 22656)
Arc Manufacturing Co. Ltd
Actarc Works, Nitshill, Glasgow SW3 (Barrhead 2293/6)
ARO Machinery Co. Ltd
190 Castelnau, Barnes, SW13 (Riverside 5434)
Aveley Electric Ltd
Ayron Road, Aveley Industrial Estate, South Ockendon, Essex (South Ockendon 3444)
D. S. Baddeley Engineering Co. Ltd
43/54 York Street, Glasgow C2 (City 7726/7)
Baldwin Industrial Controls
Dartford, Kent (Dartford 20948 & 26411)
F. Bode & Son Ltd
Buxton Road, Leek, Staffs (Leek 1451)
British Federal Welder & Machine Co. Ltd
Castle Mill Works, Dudley, Worcs (Dudley 54701)
British Industrial Gases Ltd
700 Great Cambridge Road, Enfield, Middx (4022)
British Insulated Callenders Cable Ltd
PO Box 5, 21 Bloomsbury Street, London WC1 (Museum 1600)
The British Oxygen Co. Ltd
Bridgewater House, Cleveland Row, St James, SW1 (Whitehall 9777)
The British Oxygen Co. Ltd Electric Welding Dept.
Quasi-Arc Works, Bilston, Staffordshire (Bilston 4119/)
Brent Chemical Products Ltd
Commerce Road, Brentford, Middx (Isleworth 5444-5-6)
Burnley Aircraft Products Ltd
Welding Equipment Division, Fulledge Works, Burnley, Lancs (Burnley 3121 & 3203)
Centrajet Ltd
Fossgate, York (York 54765)
Conos Spot Welding Equipment
10 Anmore Road, Denmead, Hants (Waterlooville 3267)
Cooper & Turner Ltd
Vulcan Works, Vulcan Road, Sheffield 9 (42091)
Courtburn Positioners Ltd
Stanley Works, Kempston, Hardwick, Bedfordshire (Kempston 2341/2)
Crompton Parkinson Ltd
1-3 Brixton Road, London SW9 (Reliance 7676)
Degenhardt & Co. Ltd
6 Cavendish Square, London W1 (Langham 6097)
Deloro Stellite Ltd
Highlands Road, Shirley, Solihull, Warwickshire (Solihull 2254)
Distillers Company Ltd
Chemical Division, Devonshire House, London W1 (Mayfair 8867)
Edwards High Vacuum Ltd
Manor Royal, Crawley, Sussex (Crawley 1500)
Electrothermal Engineering Ltd
270 Neville Road, London E7 (Grangewood 9911)
The English Electric Co. Ltd
Welding Equipment Division, Clayton-le-Moors, Accrington (Accrington 33241)
Esab Ltd
Gillingham, Kent (Rainham 82233)
Eutectic Welding Alloys Co. Ltd
North Feltham Trading Estate, Feltham, Middx (Feltham 6571)
Fuller Electric Ltd
Fulbourne Road, London E17 (Larkswood 2350)
Gamma Rays Ltd
Foundry Lane, Smethwick 40, Staffs (0846/7)
The General Electric Co. Ltd
Magnet House, Kingsway, London WC2 (Temple Bar 8000)
General Precision Systems Ltd
Bicester Road, Aylesbury, Bucks (Aylesbury 4611/7)
Haddon Transformers Ltd
Victoria Park Industrial Estate, Field End Road, Ruislip, Middx (Byron 9444)
Hancock & Co. (Engineers) Ltd
Progress Way, Croydon, Surrey (Croydon 1908)
F. Hirschman Ltd
Fourth Way, Exhibition Grounds, Wembley, Middx (Wembley 5341)
Hirst Electronic Ltd
Gatwick Road, Crawley, Sussex (Crawley 25721)
Holden & Hunt Ltd
PO Box 17, Coxs Lane Oldhill, Staffs (Blackheath 1196)
Industrial Descaling Tools Ltd
Lark Works, Sandridge Road, St Albans, Herts (St Albans 56026)
Interlas Ltd
Ampthill, Bedford (Ampthill 3340)
Invicta Electrodes Ltd
Bilston Lane, Willenhall, Staffs (James Bridge 3131)
Richard Johnson & Nephew Ltd
Forge Lane, Manchester 11 (East 1431)
Johnson Matthey & Co. Ltd
73-83 Hatton Garden, London EC1 (Holborn 6989)
Kerry's (Ultrasonics) Ltd
Warton Road, Stratford, London E15 (Maryland 6611)
Kimbell Machine Tools Ltd
4 South Lambeth Place, London SW8 (Reliance 6711)
Lancashire Dynamo & Crypto Ltd
Trafford Park, Manchester 17 (Trafford Park 2161)
Lancashire Dynamo Electronic Products Ltd (A member of the Metal Industries Group)
BEP Works, Rugeley, Staffs (Rugeley 371)
Lincoln Electric Co. Ltd
Black Fan Road, Welwyn Garden City, Herts (Welwyn Garden 24581)
Max Arc Ltd
Walton-on-Thames, Surrey (20497)
Marconi Instruments Ltd
Longacres, St Albans, Herts (Herts 59292)
Meritus (Barnet) Ltd
Wood Street, Barnet, Herts (Barnet 2291)
Messer Industrial Engineering Ltd
43/45 Knights Hill, London SE27 (Gipsy Hill 6111)
Morgan Crucible Co. Ltd
Battersea Works, Battersea Church Road, London SW11 (Battersea 8822)
Murex Welding Processes Ltd
Waltham Cross, Herts (Waltham Cross 23636)
C. S. Milne & Co. Ltd
Harley Works, Octavius Street, Deptford, London SE8 (Tideway 3852/3)
James Neill & Co. (Sheffield) Ltd
Napier Street, Sheffield 11 (Sheffield 26781)
New Process Welders Ltd
Nelson Place, London N1 (Clerkenwell 1381)
Oerlikon Electrodes (Great Britain) Ltd
Kelvin Way, Crawley, Sussex (Crawley 25971)
Palmer Aero Products Ltd
Penfold Street, Edgware Road, London NW8 (Paddington 8822)
Pantak Ltd
Vale Road, Windsor (Windsor 3225/6)
Pantatron Ltd
5a Princes Street, London W1 (Hyde Park 1022)
Petbow Ltd
Sandwich, Kent (Sandwich 3311)
Pollock & Peel Ltd
82/86 South End, Croydon, Surrey (Croydon 3158)
Portable Welders Ltd
Castle Mills, Buckingham (Buckingham 2233)
Research & Control Instruments Ltd
Instrument House, 207 Kings Cross Road, London WC1 (Terminus 2877)
A. Reyrolle & Co. Ltd
Hebburn, Co. Durham (Hebburn 832441)
Rockweld Ltd
Commerce Way, Croydon (Croydon 7161)
Donald Ross & Partners Ltd
Twinner Works, Gatwick Road, Crawley, Sussex (Crawley 25061)
Redifon Ltd
Broomhill Road, Wandsworth, London SW18 (Vandyke 7281)
Saturn Industrial Gases Ltd
Eri Wood, Windlesham, Surrey (Bagshot 2441)
Sciaky Electric Welding Machines Ltd
Falmouth Road Trading Estate, Slough, Bucks (Slough 25551)
Siemens Schuckert (Great Britain) Ltd.
Great West Road, Brentford Middx (Isleworth 2311)
Smiths Industrial Division
Kelvin House, Wembley Park Drive, Wembley, Middx (Wembley 888)
Solus-Schall Ltd
County Building, Honeypot Lane, Stanmore, Middx (Wordsworth 4300)
Spembly Ltd
New Road Avenue, Chatham, Kent (Chatham 44944)
Suffolk Iron Foundry (1920) Ltd
Sifbronze Works, Stowmarket, Suffolk (183)
Vacu-Blast Ltd
Wellcroft Road, Slough, Bucks (Slough 24507)
Wall Colmonoy (Canada) Ltd
68a Wigmore Street, London W1 (Hunter 2461)
Watson & Sons (Electro-Medical) Ltd Industrial Division
East Lane, Wembley, Middx (Arnold 6215)
Weldcraft Ltd
Windsor Works, Slough, Bucks (Slough 23201)
Wild-Barfield Electric Furnaces
Otterspool Way, Watford By-Pass, Watford, Herts (Watford 26091)
Yates Plant Ltd
Bedewell Works, Hebburn on Tyne, Co. Durham (Jarrow 897124)
A. S. Young & Co. Ltd
Tower Works, Woodside Lane, London N12 (Hillside 6606)

This conceptual design of a UO_2–PuO_2-fuelled steam-cooled fast breeder reactor from the Nuclear Development Corporation of America shows low capital costs due to the simple mechanical arrangement and compact core. The nuclear characteristics make it attractive for a U–233/Th system

The NDA Steam Cooled Fast Reactor concept

IT IS REPORTED that good breeding characteristics and attractive economics can be achieved from this steam-cooled fast breeder reactor fuelled with UO_2–PuO_2. For producing usable steam the Loeffler method is used. This is a forced circulation system with the drum placed at or near ground level. Saturated steam, not water, is circulated by pump from the drum through the reactor, most of the superheated steam being returned to the drum. Low capital costs of the system result from the mechanical simplicity, the compact core arrangement and the absence of large heat exchangers or complicated process systems. The high steam temperatures and pressures available from this reactor come from the use of high temperature cladding materials such as Inconel-X. The high burnup capability of the oxide fuels will make both the long-term and short-term fuel cycle costs attractive.

In this concept steam is produced in the reactor at 1400 lbf/in²g and 945°F. About one-third of this goes to the turbine. The remainder is used to vaporize feed-water in an open-type Loeffler boiler. Saturated steam from this boiler is returned to the reactor by low leakage steam circulators. The net plant efficiency is stated to be 36·5%.

Core

For a 300 MWe plant, the core would be 6 ft in dia. and 5 ft high, surrounded by a radial and axial blanket of depleted UO_2 1 ft thick. The U–238/Pu ratio is 7:1; the core being made up of 0·25 in dia. PuO_2–UO_2 rods clad in Inconel-X. The core and blanket are contained in a 10·7 ft i.d., 31 ft high pressure vessel made of 7·5 in thick plate.

The critical mass of the Pu–239 is 1660 kg and the breeding ratio has been calculated to be 1:3; the core contribution to the breeding ratio is nearly unity. The fissile content of the core remains nearly constant so that frequent refuelling is not necessary.

Voiding characteristics

The reactor can be flooded during refuelling and the consequent rise in reactivity prevented by the addition of tolerable amounts of resonance absorbers to the fuel, such as indium or hafnium. The behaviour on flooding is a result of the slight softening of the spectrum brought about by the use of steam. Although the mean fission energy is not appreciably different from sodium-cooled reactors, the population of neutrons in the energy range 5–10 keV is appreciably higher and results in significant capture in the U–238 resonance. There is also a substantial increase in reactivity on loss of coolant. When this happens the neutron spectrum is hardened and the absorption in the U–238 resonance is cut back sharply. However, the physical size of the 300 MW core leads to relatively low neutron leakage to the blanket. This relatively low increase of leakage neutrons does not compensate for the increase in reactivity due to the reduction in U–238 resonance capture. An additional effect is the increase of the thermal fission factor for Pu-239 with a rise in neutron energy, this reinforces the effect of U-238 captures. It may be necessary to provide higher neutron leakage from the core with either a smaller plant size or low L/D core. Acceptable voiding characteristics are shown with a D_2O steam-cooled plant or with a 40 MWe reactor.

With a UO_2–ThO_2 (U–233) fuelled 300 MW plant, a reduction in reactivity is obtained upon loss of coolant for the following reasons:

(*a*) The capture resonance peaks of thorium are smaller than those of U–238 and they occur at lower neutron energies.
(*b*) Available data on η, thermal fission factor, indicate a relative independence of neutron energy over the energy range in question.

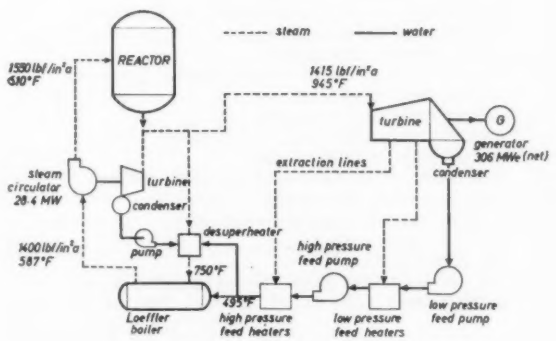
The authors have concluded from this that a steam-cooled fast breeder might be particularly attractive for a U–233/Th system.

Main data

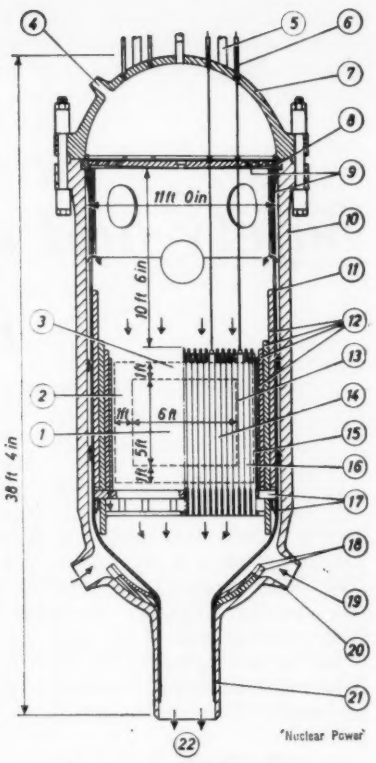
Output	300 MWe
Net plant efficiency	36·5%
Core dimensions	6 ft dia. × 5 ft high
Blanket, radial and axial (depleted UO_2)	1 ft thick
Fuel elements, PuO_2–UO_2 rods	0·25 in dia.
Cladding	Inconel-X
U–238/Pu ratio	7·1
Critical mass	1660 kg of Pu–239
Breeding ratio	1·3
Pressure vessel	10·7 ft i.d. × 31 ft high, 7·5 in thick
Steam conditions	1400 lbf/in²g:945°F

Economics

Average fuel burnup	33,3000 MWd/T
Capital cost	4·5 mills/kWh
Fuel cycle	2·5 mills/kWh
Total energy cost	7·5 mills/kWh



Steam flow diagram, about a third of the steam from the reactor goes to the turbine; the rest is used to vaporize the feed water



Elevation of the 300 MWe reactor

1 core; **2** radial blanket; **3** axial blanket; **4** steam inlet for cooling pressure vessel cover; **5** refuelling port; **6** shim rod; **7** pressure vessel cover; **8** support cylinder flange; **9** thermal shield; **10** pressure vessel; **11** support cylinder; **12** thermal shields; **13** core boundary; **14** core sub-assembly; **15** blanket boundary; **16** blanket sub-assembly; **17** bottom grid structure; **18** thermal shields; **19** saturated steam in; (**20** there are four inlet ports 90° apart); **21** thermal barrier; **22** superheated steam out

Reference

Sofer, G.A., and Hankel, R.D., Nuclear Development Corporation of America, 'Conceptual design of a steam-cooled fast breeder reactor', presented at ANS Annual Meeting, 1961.

Concluding a statistical approach to reactor reliability attention is focused on the question of capital investment and running cost

Safety and serviceability in reactor safety circuits—3

by U. BROCCARDO, Dott. Ing. Nuclear Department, Kennedy and Donkin

IT WAS STATED at the beginning of this study that the aim was the optimization of the problem; the two previous articles (June, July) have shown how, and to what extent, serviceability and safety are conflicting requirements. The best solution from a technical point of view is not always the cheapest, and to learn to find the best compromise in engineering problems is becoming increasingly important with the trend towards automation. This concluding article will try to focus the problem.

OPTIMIZATION OF THE PROBLEM

The two aspects of serviceability and safety come into consideration in every engineering problem and even in everyday life, e.g. while buying a car. By spending a certain sum of money one expects to get a certain service from the car together with a certain degree of safety in operation, but a faster car is bound to be less safe.

In more general terms, the question is one of capital investment and running cost, the latter being made up of two components, one relevant to serviceability and the other to safety. By increasing the capital investment one expects to increase serviceability, i.e. to decrease maintenance expenditure, and to increase safety, i.e. to decrease the number of likely accidents or the value of the insurance premiums.

It is clear that, to optimize a system, one has to minimize a sum consisting of three terms, calculated over one year or the life of the system.

1. Capital investment, including the interest and the amortization rate.
2. Fraction of the running cost which is related to serviceability.
3. Fraction of the running cost which is related to safety.

It seems better to consider items (2) and (3) separately, as variations of the parameters of the problem produced in the variations in opposite directions. The trend towards automation tends to shift expenditure from items (2) and (3) to item (1) and this is possible only to the extent that money is available.

NOMENCLATURE

f	safe fault rate
g	unsafe fault rate
f_c	channel safe fault rate
g_c	channel unsafe fault rate
f_g	expected occurrences of spurious trips for the group of channels over one year
g_g	expected occurrences of unsafe conditions for the group of channels over one year
f_l	line safe fault rate
g_l	line unsafe fault rate
f_s	expected occurrences of spurious trips for the safety system
g_s	expected occurrences of unsafe (dangerous) conditions for the safety system
f_r	guard line monitoring relay safe fault rate
g_r	guard line monitoring relay unsafe fault rate
f_1	safe fault rate for a good channel
f_2	safe fault rate for a medium channel
f_3	safe fault rate for a poor channel
g_1	unsafe fault rate for a good channel
g_2	unsafe fault rate for a medium channel
g_3	unsafe fault rate for a poor channel
f_t	frequency of the maintenance routine test
n_1	number of good channels in one safety line
n_2	number of medium channels in one safety line
n_3	number of poor channels in one safety line
n	total number of channels
p	probability of a fault, safe or unsafe
p_c	probability of a safe fault for the channel
q_c	probability of an unsafe fault for the channel
p_g	probability of a spurious trip for the group of channels
q_g	probability of an unsafe condition for the group of channels
p_l	probability of a safe fault for the line
q_l	probability of an unsafe fault for the line
p_s	probability of a spurious trip for the system
q_s	probability of a dangerous condition for the system
m	number of safety lines of the system
r	index of the trip arrangement
mCr	number of combinations of m elements in group of r
t_s	average duration of a safe fault
t_u	average duration of an unsafe fault
t_d	average duration of a fault, safe or unsafe
t_t	average duration of the routine test
t_v	time during which the channel is working properly
t_f	time during which the channel is faulty
t_v	average time taken to repair a safe fault
C_l	cost of a safety line
C_t	cost of spurious trip
C_a	cost of an accident caused by maloperation of the safety system

As soon as the amount of money available on the market shrinks, the interest rate will tend to go up, so that money becomes available only for the ' commanding heights ' of the economic life.

With reference to the safety circuit, the first term can be considered proportional to m, the number of safety lines fitted. In the cost of a guard line, C_l, the cost of the relevant thermal column and of all the equipment making up the relevant channels must be included. A figure of £10,000 can be assumed to represent the order of magnitude of C_l.

The second term is proportional to the number of spurious trips. The cost of one spurious trip, C_t, in an interconnected system, can be assumed to be the differential cost of generating electricity in the most inefficient station of the system; this station would be shut down if the nuclear station were running. Taking a 250 MWe reactor with a fuel cost of 0·18 d/kWh being replaced by a conventional station with a fuel cost of 0·68 d/kWh, and assuming that the spurious trip puts the reactor out of commission for 24 hours, its cost would be £12,500.

The third term is proportional to the cost of an accident, C_a, caused by an unsafe condition originated within the safety system. It is worthwhile emphasizing that it has been pessimistically assumed that every unsafe condition is a dangerous one. While a study of the possible accidents so arising would be desirable, a major accident, such as a fuel melt down, can be excluded. The order of magnitude of C_a can be evaluated from the value of the third party insurance against the maximum credible accident, i.e. £5 millions. It can be concluded that C_a is of the order of 100 times C_t.

The theoretical analysis developed in the preceding articles provides a way to calculate the number of expected spurious trips and of expected accidents. It also points out the parameters on which the problem depends. Such a parameter as $f_t=\frac{1}{2t_u}$ should be fixed by the designer and not left to the discretion of the staff operating the station.

MEANS OF ENHANCING SERVICEABILITY

There are four means of increasing serviceability, namely:

- **a** Application of the coincidence principle, i.e. increasing the index r of the arrangement, for a given value of m
- **b** Shorting out of the faulty channel during maintenance, i.e. decreasing t_s
- **c** Splitting of the safety system into a number of smaller systems
- **d** Use of a ' double ' system instead of a single system. This can be considered a limit case of splitting.

Means **a** and **b** have a negligible effect on term 1 of the above sum, but while enhancing serviceability, they worsen safety. Methods **c** and **d** do not influence appreciably terms 1 and 3, they only affect term 2 and, therefore, seem preferable to the other two.

MEANS OF ENHANCING SAFETY

There are three means to enhance safety, namely:

- **a** Increasing the number of safety lines fitted, i.e. increasing m
- **b** Increasing f_t, i.e. decreasing t_u
- **c** Applying the ' backing up ' principle.

The first method affects all the three terms of the sum. The second seems at first sight only to affect terms 2 and 3. However, if the increase of f_t involves increase of staff, say of one skilled person to do the routine test, the economic effect is more difficult to take into account. For present purposes it seems that it could be accounted for in term 1, under the form of a yearly sum which has to be paid. During the life of the station this sum could be of the order of £10,000, which can be written in the form of $C_f m$.

Means **c** only affects term 3, as it only requires an accurate setting of the trip levels of the channels, so that one of the functions covering a certain fault is really capable of tripping the reactor before the other functions backing it up. It seems therefore preferable to the other two.

USING A COMPUTER

Should realistic figures for C_1, C_t, C_a, f_c and g_c be available, the optimization can be attempted using a digital computer. The equation to deal with in the case of a single system, without backing up features, without shorting out during maintenance and with shorting out during routine test, will be :

$$C_l \times m + C_t\,(mPr)\,f_t^{\,r} t_s^{\,r-1} + C_a[mP(m-r+1)]$$
$$[g_1^{\,m-r+1} t_u^{\,m-r} n_1 + g_2^{\,m-r+1} t_u^{\,m-r} n_2$$
$$+ g_3^{\,m-r+1} t_u^{\,m-r} n_3] \qquad (32)$$

The following values are suggested for the parameters:

$m,r = 2,2;\ 2,3;\ 3,3;\ 2,4;\ 3,4$

$t_s = 10^{-4};\ 10^{-3}$

$t_u = 10^{-2};\ 10^{-3};\ 10^{-4}$

This gives altogether 20 different combinations.

More elaborate formulae can be worked out for the cases of double systems, with backing up features etc. It does not seem possible to establish a unique formula, including all the possible cases under the form of an increased number of parameters.

CONCLUSIONS

Lack of experimental data, i.e. of reliable statistics on the operation of the safety circuits, prevents drawing a conclusion in the form of the choice of the best values for the parameters. It is possible that, by varying the parameters, more than one satisfactory solution can be found.

However, it is hoped that these articles may suggest a new approach to the problem, since quantitative knowledge is the only certain knowledge.

It seems that some of the concepts developed, namely the mathematical treatment of the coincidence of events having a limited duration and the way to optimize the system, could be applied to other fields without difficulty.

The author would appreciate comments and data enabling him to check the theory against experience.

Acknowledgments

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The work was carried further after the author joined the Nuclear Department of Kennedy and Donkin and he wishes to thank the firm and his colleagues, particularly Dr J. R. Williams, for their help.

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POWDER METALLURGY IN THE NUCLEAR AGE

A report on the Fourth International Plansee Seminar by J. W. Taylor, Ph.D., Research Dept, Babcock & Wilcox Ltd, Renfrew

THE MATERIAL PRESENTED at the Seminar covered the full range of nuclear components where powder metallurgical techniques are applicable.

Some forty papers and a number of discussion topics were presented under the following general headings.

Metallic fuels

An opening paper summarized the general property requirements of fuels, canning alloys, coolants, moderators, control and shielding materials in nuclear energy applications while the first specialist paper outlined French CEA experience in the preparation of uranium powder on a pilot plant scale by the calcium reduction of uranium oxide; the essentially spherical nature of this product made it a useful starting point for other fuel materials such as carbides, nitrides, etc. Recent UK experience, at Harwell, in the fabrication of plutonium powder by pressing and sintering techniques was outlined; the same paper presented preliminary work on the consolidation of plutonium oxide/uranium oxide stainless steel cermets. An interesting contribution from the Vienna technical high-school discussed the preparation and properties of metal powders, including uranium, prepared by an electrolytic amalgam technique.

Oxide fuels and cermets

Recent data relating to the mechanism of sintering of oxides in various atmospheres were presented by the University of Notre Dame, USA, and factors responsible for the dependence of sintering rates of uranium oxides on composition were considered. Data on the sintering behaviour of mixed uranium oxides and plutonium oxides were presented from the AERE, Harwell, and from the CEN, Belgium, while an Austrian paper outlined the high temperature behaviour of uranium oxide with alumina and zirconia. Japanese experience in the uranium oxide field was covered by two papers. The first detailed a comprehensive catagorization of powder properties in relation to chemical production route and to their ultimate use for component fabrication. The second considered the distribution and high temperature behaviour of fission products in a uranium oxide/graphite fuel element system. An Indian paper gave a similar survey of uranium oxide powder properties carried out by the AEA, Trombay, whilst experience at Grenoble in the production of oxides of different reactivities was presented by the French CEA. This paper also considered the extrusion and sintering of uranium oxide bars and tubes.

American contributions dealt with several aspects of cermets. One was concerned with a statistical analysis of the probable spacing and contact of particles in a two-component system while a second referred to dispersed phase systems including coarse, i.e., 100–400 micrometres, and fine, i.e., one micrometre or less, dispersion types. A BMI, Ohio, paper outlined consolidation experience of dispersion-type elements containing 60–90 vol—% uranium oxide in stainless steel, niobium, molybdenum, and chromium; mechanical and physical property data were included.

In discussion, recent Swedish experiments were outlined in which uranium oxide at 1800–2000°C showed the formation of free uranium under certain conditions, while the UKAEA, Harwell, reported on a recent analysis of much of the available data on fission product gas release from this material, and on recent experiments on gas release under various thermal treatments.

The Plansee Seminars are now well recognized as one of the principal international conferences on powder metallurgical science and technology, organized under the auspices of Metallwerk Plansee, Reutte-Tyrol, Austria. The fourth, held in Reutte in June, 1961, was strongly biased to developments of powder metallurgical science and technology as applied to reactor materials. Over 300 representatives attended with contributions not only from countries well established in the nuclear energy field, but also from relative newcomers such as Japan, India, Sweden, Austria and Belgium.

Uranium compounds

Fabrication procedures for uranium monocarbide were covered by a number of papers. British techniques reported included direct reaction of the metal powders, cold pressing and sintering, and arc-melting. The French described sintering with simultaneous chemical reaction and electron beam welding, and the Americans methods involving cold compacting followed by sintering, and hot pressing. A German paper discussed the preparation of uranium carbide by an oxide/graphite reaction technique and the subsequent fabrication of this into a fuel element by a swaging procedure. The American paper also referred to the formation of uranium nitride by similar techniques while the Plessey Co. experience in the preparation and physical properties measurement of the tetraborides, silicides and borocarbides of uranium and thorium was also recorded. A very comprehensive French paper dealt with the preparation, properties and phase relationships of solid solutions of oxides and carbides of uranium and plutonium; similar UKAEA work on the plutonium-uranium-carbon system was included. Los Alamos, USA, had prepared plutonium carbides and uranium-plutonium carbide solid solutions and also plutonium dioxide cermets with molybdenum.

Phase constitution work from Sheffield University dealt with uranium carbide with chromium, iron, nickel and the compound UFe_2 while ternary diagram studies of uranium, thorium, and metalloids were outlined in discussion by Metallwerk Plansee, Austria; the latter was of particular interest in relation to the HTGC type of system.

Constructional materials

Beryllium powder fabrication procedures were considered in two general papers, one from the UKAEA, AWRE, the other from the Péchiney Co., France, while the effect of neutron irradiation at temperatures below 350°C on the tensile properties of beryllium was discussed in a paper from AERE, Harwell. In the discussion of the beryllium papers, interesting UK data was presented on the mechanical properties of sheet material fabricated direct from ingot; the economic importance of such developments was stressed.

The fabrication, physical properties, chemical reactivity, and irradiation stability, including helium retention, of the rare earth borides were detailed by the US GEC; future areas of application considered include the use of these materials in a metal matrix and also their use in high temperature gas-cooled reactors.

A paper from the BSA group, referred to the production of pre-alloyed powders and their current and future applications in the nuclear energy field; attention was also given to the production of porous filter materials.

High melting metals

Papers in the first of these two sections touched on such specialized topics as techniques for the preparation of dense spheroidized particles, the coating of particles by vapour phase deposition, and the production of a dispersion-hardened uranium by the introduction of uranium oxide on the initial metal particles. An interesting French paper from Saclay gave data on the production of metal-clad uranium-aluminium and uranium oxide-stainless steel dispersion-type elements by a co-extrusion technique. Nuclear Metals Inc., USA, outlined powder extrusion procedures for a number of systems including metal-clad/ceramic core elements, metal-clad/dispersion-core elements and control rods, beryllium, etc. The fabrication of breeding elements from thorium powder was also included in a German paper.

High temperature applications of more conventional powder metallurgical products included beryllium, carbides, and other composite materials in rocket and missile applications; two aspects of tungsten technology dealt with the fabrication and properties of a wide range of tungsten cermets and with various protective coatings for tungsten particles. British papers reported work on the ruthenium-molybdenum system and also mechanical property data up to 2200°C on niobium, tantalum, tungsten, molybdenum, and iridium. An Austrian paper gave new optical techniques for the study of high tempering sintering processes and some results.

(*The full proceedings of the conference will be published later.*)

Application of conventional nuclear radiation detectors for locating uranyl deposits and accumulations of plutonium in chemical plants are discussed

Instrumentation for criticality protection of chemical plants

by D. K. CARTWRIGHT, B.Sc., and M. J. TODD, B.A. UKAEA (Reactor Group), Capenhurst

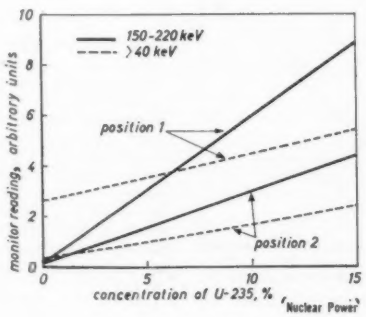
ACCUMULATIONS OF FISSILE MATERIAL can occur in plants operating with gaseous uranium hexafluoride (UF_6) by condensation or by reactions of uranium hexafluoride with other substances. Reaction is most likely to be caused by water vapour entering with inleaking air, although gross water inleakage from coolers is a possibility: this latter effect can usually be detected by its effect on plant operation. Detection of deposits formed by water inleakage over a period of days or longer is more difficult. To meet this problem, the use of nuclear radiation detectors was investigated: neutron monitors had previously been found satisfactory for detecting condensed uranium hexafluoride (*5*).

Choice of detectors

As deposits have to be detected inside plant components, only the γ-radiations and neutrons emitted are useful for detection purposes.

From deposits a few days old the γ-radiation will be mainly from U-235 (184 keV) and its daughter Th-231 (~90 keV) although from deposits of low U-235 enrichment the radiation will increase because of the growth of Th-234, the daughter of U-238. With a deposit of natural uranium, for example, the count rate from a 1 in thick sodium iodide scintillation counter biased at 40 keV increases by a factor of five because of ingrowth of Th-234, and in the energy band 150-220 keV the reading is doubled.

To detect the low-energy γ-radiations, two detectors were used. One was a portable transistorized scintillation detector using a 1 in high × 1½ in dia. sodium iodide crystal. The monitor was biased at about 40 keV and calibrated in mr/h using radium. The other detector was a conventional scintillation spectrometer using a sodium iodide crystal 1 in high by 1½ in dia. normally operated to detect radiation in the energy band 150-220 keV.



Variation of background with U-235 concentration for two typical positions in the plant (Fig. 1)

In addition to the normal radiations from uranium, neutrons are emitted both by (α, n) reactions in light elements, principally fluorine, and by spontaneous fission of U-238. As most of the neutrons come from (α, n) reactions, the neutron emission will depend mainly on the α-activity of the specimen and on the composition of the deposit. The neutron emission was measured with four 1 in dia. boron trifluoride counters each 6 in long, mounted in a paraffin block of size 5 × 5 × 10 in.

Criticality hazards in nuclear chemical plants have been discussed by a number of workers; e.g. Nicholls and Gillieson (*1*), Callihan (*2*) and Hall (*3*). They point out that even with 'eversafe geometry' there is still the possibility of dangerous accumulations of activity. Inleakage of water, for example, could cause a dangerous condition.

Instruments are required which will detect and locate undue build-up of fissile material. It may also be desirable to have further instrumentation to locate the site accurately and monitor the subsequent activity. For instance, at Marcoule fission chambers are used to detect accumulations of plutonium (*4*).

The sensitivity of each counter to thermal neutrons was 5 counts per n/cm², and the sensitivity of the detector to fast neutrons, measured with a polonium-beryllium source, was 5 counts per n/cm².

Experimental work

The radiation background was measured at various positions on stages throughout a section. These positions were chosen so as to cover the full range of background intensities, and included those where deposits were most likely to form. In general, the plant layout was such that at similar positions on stages operating at roughly the same concentration the background was the same.

Detection of deposits with γ-ray monitors In general, in a particular section of the plant, the background of γ-radiation with energy exceeding 40 keV and in the band 150-220 keV was proportional to the U-235 concentration in the stage. At low U-235 concentrations (up to about 10-15%) the variation for energies exceeding 40 keV was linear, extrapolating at zero concentration to a low value, and so indicating that Th-234 was usually evenly distributed. For some positions the extrapolation was significant, indicating a build-up of Th-234 (see Fig. 1 and Table 1).

To measure the γ-radiation from deposits, artificial deposits

TABLE I *Maximum radiation background at components of a typical plant handling uranium hexafluoride*

CONCENTRATION OF U-235, %	RADIATION BACKGROUND Portable monitor, mr/h	RADIATION BACKGROUND γ-energies in range 150-220 keV, counts/s
90	0·8	2,800
10	0·46	650

Note: *the sizes of components at 90% and 10% enrichment are different*

were prepared by hydrolyzing gaseous uranium hexafluoride from the plant. The composition was roughly $UO_2F_2.2H_2O$ and the density about 2g/cm³. Deposits weighing about 600g were prepared with U-235 concentrations of about 0·7 and 7%, and one weighing about 20g with a U-235 concentration of 50%.

Measurements were made several days after initial hydrolysis so that Th-231 was in equilibrium and the contribution from Th-234 and Pa-234 was small. These showed that, for approximately spherical deposits, the monitor reading (I) is approximately given by equ (1) below, provided that the deposit is several diameters from the detector. For closer distances, the radiation is reduced to values up to one-half of that given by equ (1). This relationship has the expected form, as the radiation is effectively emitted from a surface layer.

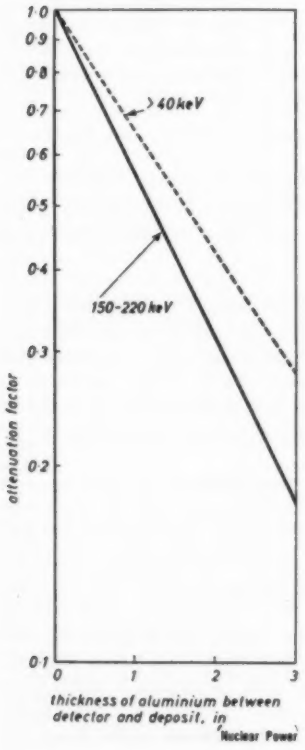
$$I=\frac{KAm^3c}{d^2} \qquad (1)$$

where c=U-235 concentration, %; and A=an attenuation factor depending on the absorber between the deposit and detector (see Fig. 2); d=distance between the deposit and the detector, cm; m=mass of uranium in the deposit, g; K=0·10 for monitor biased at 40 keV (I is expressed in mr/h) and=260 for monitor reading in the range 150-200 keV (I is expressed in counts/s).

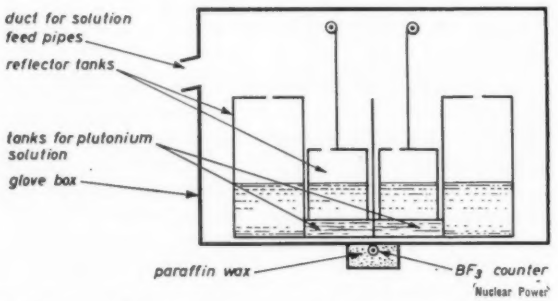
Assuming that an intensity reading from a deposit equal to the background radiation is required for detecting the deposit, equ (1) may be re-arranged to enable the mass of uranium in the deposit (m) to be detected in a background B. The re-arranged equation is:

$$m=\left(\frac{B\,d^2}{KAc}\right)^{3/2} \qquad (2)$$

From the combination of this relationship with measured backgrounds, it is possible to detect masses which are small compared with the safe mass, provided the detector is close to the deposit and little absorber is present. For example, for the maximum backgrounds at 90% and 10% U-235 given in Table 1, masses of uranium at 6 in from the detector of about 0·130 and 1·3 kg can be detected with a monitor biased at 40 keV. For the position chosen at 10% the low-energy background is high because of the presence of Th-234. At this position 0·5 kg of uranium can be detected using a monitor biased to detect energies in the range 150-220 keV. Even for the monitor biased at 40 keV these masses are small compared with the maximum safe masses of likely deposits, which for 90% and 10% U-235 are greater than 11 and 24 kg of uranium, respectively. For configurations other than spherical, equ (2) is not valid. However, because of the increase of area relative to mass of other shapes, and the small penetration of the γ-rays (relaxation length ~3-4 mm) it is expected that the radiation intensity from a given mass would not be less than that given by equ (1). For example, for slab deposits this has been found to be true in a typical plant, provided that the deposit is not thicker than about 1 cm and that the linear extent of the deposit does not exceed several deposit-detector distances.

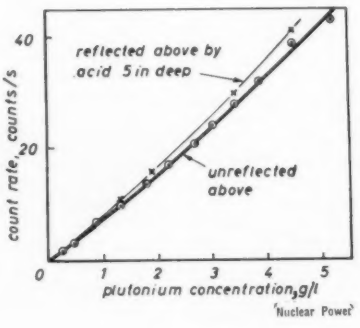


Absorption of γ-rays from a uranium deposit by aluminium; a thickness of 4 in of aluminium reduces the neutron count rate by 20% (Fig. 2)

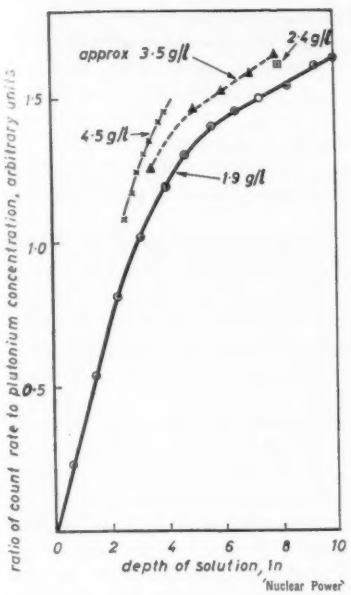


Arrangement for measuring neutron count rate from plutonium solutions (Fig. 3)

Detection of deposits with a neutron monitor As the natural background of the neutron counter was high, about 10 counts/min, little increase in count rate above this was found until the concentration reached about 70% U-235. The count rate



Variation of count rate with plutonium concentration from a solution 3·5 in deep in one 12 in wide stage, for a concentration range up to 5 g/l with and without reflection by a 5 in deep layer of acid; both curves are linear up to 2 g/l (Fig. 4)



Variation of count rate with depth of plutonium solution, at concentrations below 2 g/l the specific count rate is nearly independent of plutonium concentration (Fig.5)

then increased to a value of 96 counts/min at about 90% U-235.

At U-235 concentrations above a few per cent, the neutron emission will be approximately proportional to U-234 concentration; while at lower concentrations a small contribution from U-238 (α, n) reactions and from spontaneous fission of U-238 would be expected; for natural uranium the U-238 contribution is estimated to be about 40%.

Because of the low absorption cross-section, the neutron emission from a deposit will be proportional to the mass of uranium although the neutron emission will depend slightly on the composition of the deposit. For the likely range of composition of deposit, the variation is not expected to be bigger than 30%, although for condensed uranium hexafluoride the neutron emission will be approximately double that from uranyl fluoride. Moreover, the absorption of neutrons by plant components is small (Fig. 2).

The neutron emission from a mass of $UO_2F_2.2H_2O$ containing 200 g uranium with a U-235 concentration of 47% was found to be equivalent to 0·8 n/s per kg. On the assumption that the U-234 concentration is proportional to U-235 concentration c (which is pessimistic at high enrichments), an indication of the mass of uranium (m) which can be detected is given by:

$$m = \frac{2{\cdot}5Bd^2}{c} \qquad (3)$$

where B is counter background, counts/min; d distance between deposit and counter, cm. This indicates that, for a deposit 6 in from the detector, masses or uranium of about 0·5 kg can be detected at both the 90% and 10% concentration levels of U-235.

Deposits can thus be detected by both γ and neutron counters. In general, however, γ-detectors are preferred; not only are they usually more sensitive, but the high counting rate means that measurements of sufficient accuracy can be made in several seconds compared with the several minutes required for a neutron counter. The neutron counter, however, is useful where detection is required in massive components where attenuation of γ-rays is large and also where large amounts of Th-234 may have accumulated as a result of condensation and subsequent evaporation of uranium hexafluoride. In the latter case, a γ-detector biased at 40 keV may give grossly misleading readings.

DETECTION OF PLUTONIUM

In chemical plants for the separation of plutonium from irradiated fuel, dangerous build-up of plutonium may occur, and it is desirable to have a measure of plutonium hold-up in the actual stages of the plant. In addition, particularly when the time for a dangerous build-up of plutonium may be short, it may be necessary to have installed instruments.

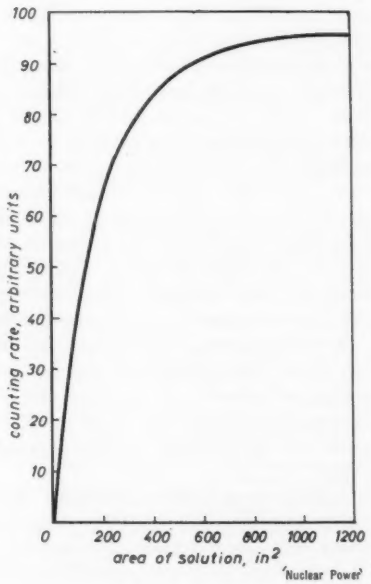
Factors determining neutron count-rate

Neutrons are emitted from plant solutions mainly because of (α, n) reactions in oxygen and carbon, and by spontaneous fission of Pu-240. In most stages of a typical separation plant, the main α-activity is caused by plutonium; transuranic elements, e.g., Am-241 and Cm-242, are usually removed in the early stages and uranium α-activity (which is 10^{-5} of that of an equal mass of plutonium) can usually be neglected.

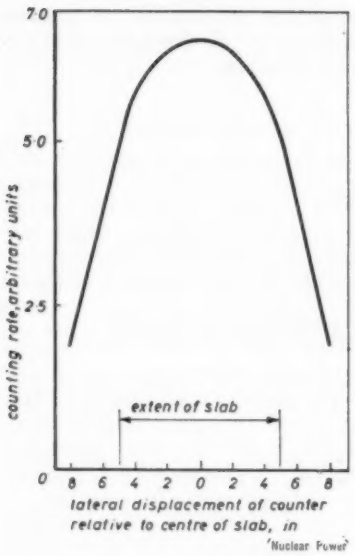
The neutron emission from a plutonium solution depends on the concentration and isotopic composition of the plutonium and also on the chemical composition of the solution. The count rate recorded by a particular detector arrangement will also depend on the moderating and absorbing properties of the solution and the vessel, the volume and configuration of the liquid, and the proximity of neighbouring vessels. In the settler tanks of a typical plant, an organic solvent will be floating on the acid phase, and the reading of a monitor placed under a particular stage will have contributions from both phases. It is desirable to place the counters under the stages, to be out of the way of other plant components.

Experimental work

Two separate series of experiments were performed. In the first, the neutron emission from plutonium containing 3·8% Pu-240 in 2N nitric acid was measured in tanks designed to simulate the configuration of a typical plant. In the second, the neutron emission from 10-ml samples containing about 100 mg of plutonium was measured. This was to determine the neutron emission from various chemical and isotopic com-



Variation of count rate with area of a 1 in thick layer of plutonium solution. The counter is under the centre of the layer, and the layer is fully reflected by water above (Fig. 6)



Count rate profile under a slab of plutonium solution 10 in × 10 in × 1 in deep, of concentration 9 g/l. The layer is reflected above by a 6 in layer of 2N nitric acid (Fig. 7)

positions relative to that from the material used in the large-scale experiments.

A diagram of the experimental arrangement used for simulating plant settler tanks is shown in Fig. 3. Four stainless steel tanks, each 1 ft wide, 2 ft deep and 3 ft 6 in long were used. Plutonium solutions of concentration 80 g/l could be fed to either of the centre tanks, in known amounts. By adding acid, the concentration of plutonium and the depth of solution was varied over fairly wide limits; the mass of plutonium was limited to 300 g, however, by safety considerations. The two end tanks contained water.

To estimate the effect of reflection by the solvent layer, two tanks were fitted; these could be lowered into the two centre tanks to any desired depth. The amount of solvent in these tanks could also be varied.

Neutrons were detected by a 5 cm dia. boron trifluoride proportional counter with a sensitive length of 15 cm (nominal sensitivity to thermal neutrons of 25 counts per n/cm²). This was embedded in a block of paraffin 22 cm wide, 30 cm long and 12 cm deep, the arrangement being chosen as the most sensitive. The counter was mounted on a light mobile trolley under the tanks of plutonium, as shown in Fig. 3.

Neutron count rate and its dependence on concentration and depth Figure 4 shows that the count rate at typical high operating plutonium concentrations is sufficiently high for measurement, e.g., at 1 g/l the count rate is 410 counts/min, compared with a typical counter background of 20 counts/min or less. For concentrations up to about 2 g/l the count rate varies linearly with concentration, while above 2 g/l the rise is more rapid, indicating that neutron multiplication is occurring. The increase in count rate with depth, shown in Fig. 5, is a function of plutonium concentration.

As the moderating properties of acid and the typical solvent are similar, the variation of count rate with depth of solution enables an estimate of the count rate from a solvent phase floating on an acid phase to be made. Allowance has to be made for the different specific emission from the solvent phase.

Interference from neighbouring stages By measuring the count rate profile under a single 12 in stage, it was shown that the count rate falls to about 14% under a neighbouring stage (for plutonium solutions greater than 3 in deep, and reflected by a layer 5 in deep). This was confirmed by filling two tanks to a depth of 5 in with solution having a plutonium concentration of 3·5 g/l. This shows that under these conditions neutron multiplication was not significantly increased by neighbouring stages.

Neutron count from thin layers of solution To enable the count rate from localized accumulations of plutonium to be estimated, the count rates from 1-in layers of plutonium were measured (Figs. 6 and 7).

Dependence of neutron emission on composition of the solution The neutron emission of small samples (~10 ml) of solution containing about 100 mg plutonium was measured relative to that from plutonium containing 3·8% Pu-240 in 2N nitric acid. This was done by placing the samples in turn in a block of perspex in which six 1 in diameter enriched boron trifluoride counters were embedded.

The neutron emission increased by a factor of 1·6 as the Pu-240 content was increased from 3·8% to 9%; this is consistent with an (α, n) yield of about 0·05 neutrons per 10^6 α-particles, in agreement with Roberts (*6*). The neutron yield from plutonium in the solvent was about 70% of that from plutonium in 2N nitric acid.

The effect of other changes in composition on neutron yield was not measured, but likely variables have been estimated to have little effect, e.g., changes of normality up to 10N and of uranium content, when its α-activity is negligible, up to concentration of 100 g/l.

Application to criticality alarm systems The application of the results given above depends on the detailed design of the chemical plant. In general with a mixer-settler plant, the neutron emission from an aqueous phase is adequate to enable accumulations to be detected well before dangerous conditions are reached. It is not normally possible, however, to measure plutonium concentrations because of variations in solution depth, changes in isotopic composition and interference from other vessels. In addition, it may not be possible to distinguish between precipitates or sludges and high plutonium concentrations in bulk solution.

To detect high concentration of plutonium in the solvent phase, it may be necessary, because of absorption of neutrons in the aqueous phase, to mount counters either above contactors or under vessels containing the mixed phases.

If the reasonable assumption that the neutron emission from likely sludges is comparable with that from solutions is made, precipitates and sludges can be detected, provided that a close spacing of detectors is used. For example, a mass of 220 g of plutonium with a concentration of 6·6 g/l can be detected in a vessel containing plutonium with a concentration of 1 g/l, provided that the counter is not farther than 9 in from the deposit. In practice it may be necessary on economic grounds to limit the number of installed detectors to places where deposits are most likely to occur, and to use portable monitors to scan the plant periodically.

ACKNOWLEDGMENTS

This paper is published by permission of Mr R. V. Moore, Managing Director, and Dr H. Kronberger, Deputy Managing Director, of the UKAEA (Reactor Group). Messrs B. G. Ferguson and T. Downs assisted with the experimental work on uranium and plutonium. The uranium deposits were prepared by Chemical Services Department, UKAEA (Production Group), Capenhurst.

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5. Seymour, F. D., Hughes, I. and Bisby, H., AERE, Harwell. Private communication (1955).
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Points from Papers

reports, meetings, conferences

IMPROVED FLUX MEASURING

Due to the unfavourable ratio between the light water attenuation of the neutron flux (~1 decade/15 cm H_2O) and of the gamma flux (1 decade/30 cm H_2O) in a tank type reactor like DR2, it is often difficult to achieve sufficiently large measuring ranges on the linear and logarithmic flux measuring channel. Using Westinghouse CJC type detectors with 2-decade electrical gamma compensation, improved measuring conditions were obtained by shielding the detectors by means of lead covers placed around the instrument thimbles in the reactor tank. Since these measurements have been made the reactor has operated at 360 MWd without further difficulties from gamma background.

Influence of the gamma background on the measurement ranges of neutron detectors in DR2. J. Rasmussen and O. Walmod-Larsen. Danish AEC. **Risφ Report 24.** 12 pp. 1961.

KEWB EXPERIMENTS

Two core vessels one spherical (operated from 1956-1959) and the other cylindrical (in operation since March 1960) have been used in a comprehensive series of tests into the safety of aqueous homogeneous reactors. These, commonly known as ' water boilers ', are fuelled with a solution of uranyl sulphate. The report outlines some of the operating difficulties and describes experiments carried out. These were mainly concerned with the dynamic behaviour of the reactors after considerable step and ramp inputs of activity. The effect of variations in initial power, pressure and temperature as well as the effects of variation in the uranium concentration were examined. Other experiments determined the effect of reflector delayed neutrons by using an unreflected core.

Reactor operating aspects of the kinetic experiment water boiler (KEWB) program. J. H. Roecker. Atomics International. 14 pp. Paper presented to the 1961 Annual Meeting of the American Nuclear Society.

RADIATION IN INDUSTRY

The application of radioisotopes to many areas of industrial process control has seen very little experimental study. Backed by the AEC Office of Isotopes Development, a BMI study shows the advantages of using intrinsic tracers in purification process control, simplifying stream analysis particularly where hot, corrosive or toxic materials are being handled. The process chosen for study was the hydrometallurgical ammonia leach nickel refining process, one used in the production of cobalt, zinc, copper and other metals, with the specific application of controlling iron removal. Standard gamma scintillation probes were used as detectors and the geometry used for the detection systems gave an overall counting efficiency of 6% based on a standard solution count. The radioactivity level in the feed solution was read out on a ratemeter; that of the filtrate either on a similar ratemeter or scaler. The results of deliberate transient incidents, corroborated by chemical analysis of the filtrate, demonstrated the capability of the radioassay system in giving an accurate and continuous analysis.

Application of intrinsic radiotracers to the control of an iron precipitation process. J. F. Kircher *et al.* Battelle Memorial Institute. 17 pp.

Another paper indicates how, with portable neutron sources, recent developments in automation and computer data handling permit the consideration of neutron activation analysis for industrial chemical process control. Essentially, an analogue computer is programmed to operate from the output of a pulse height analyser, which in turn is fed by a gamma scintillation detector. Through the use of the pulse height analyser and detection system, it is possible to monitor an irradiated stream for the presence of a preselected amount of radioactivity and thus control the input of stream constituents so as to obtain the predetermined activity levels by means of a servo-actuation system.

Uses of Neutron activation analysis in chemical process control. Lloyd Fite *et al.* A. & M. College of Texas. 8 pp. Both papers were read to the 1961 Joint Congress of the American Institute of Chemical Engineers and the Chemical Institute of Canada, Cleveland, Ohio.

FUEL CLADDING FOR ML-1

Out-of-pile tests were performed on six Hastelloy and Inconel alloys to determine a suitable cladding material for the nitrogen cooled 500 kWe ML-1 reactor. The requirements were for an alloy with relatively low thermal and epithermal neutron absorption cross-sections capable of withstanding corrosion and gross microstructural changes over a 10,000 h life at 1750°F. Hastelloy-X appears to be satisfactory from both nuclear and metallurgical standpoints. Good quality seamless and welded tubing can be obtained and welding is easily accomplished.

Evaluation of metal alloys for cladding the fuel elements in a high temperature nitrogen-cooled reactor. J. S. Brunhouse and G. W. Titus. Aerojet-General Nucleonics. 17 pp. Paper presented at the American Nuclear Society Meeting, Pittsburgh, 5-7 June, 1961.

BERYLLIUM RESEARCH

Beryllium is being considered as a possible canning material for the projected Australian HTGCR, with beryllia as a moderator and austenitic stainless steel as an alternative for the can and as a structural material in the hotter part of the circuit and core. Cr, Mo types of low alloy steels are being looked at for the hot gas ducting and heat exchangers. A programme of work to determine the limiting operating conditions to which each of these materials can be subjected in a CO_2 system is reported. Variables such as temperature, pressure, surface preparation, gas velocity and impurity contents have been studied using autoclaves, thermobalances and dynamic loops.

It is shown that, with gas containing 20 p.p.m. moisture, Be cannot be used at 650°C and above 22 kg/cm² pressure. Rate of attack is very dependent on gas pressure and a much higher gas purity than the commercially available is necessary for further temperature advances. A gas purification system has been developed which lowers the moisture content of the gas to 1–2 p.p.m. No corrosion problems were experienced using beryllia up to 800°C but some little difficulty may be encountered due to the evolution of occluded and adsorbed gases on startup. Oxide scaling in Mo, Cr steel at 450°C eliminates it as a structural material. Austenitic 18·8 Ti stabilized stainless steel can be used up to 700°C.

Corrosion of beryllium, beryllia, and selected steel in carbon dioxide. Dr A. Draycott. Australian AEC. 29 pp. Paper read at the 1961 Achema convention, Frankfurt.

NUCLEATE POOL BOILING

This report describes an equation for the heat flux in nucleate pool boiling obtained by a statistical analysis. The equation is able to describe the heat flux with an absolute deviation of 40% compared with experimental data from the literature. This is the best that it is considered possible with this equation, which has eight variables but does not include the nature of the heat transfer surface as a variable.

A statistical analysis of nucleate pool boiling data. G. A. Hughmark. Ethyl Corporation. 10 pp.

New Reports

Radioisotope data. R. A. Allen, D. B. Smith and J. E. Hiscott. UKAEA, Wantage Research Laboratory. **Report AERE R 2938.** 200 pp. Available from HMSO 8*s*.

UKAEA and associated British work on controlled thermo-nuclear reactions. Bibliography compiled by C. S. Sabel. AERE Harwell. **Report AERE Bib 124.** 46 pp. Available from HMSO 7*s*.

Recommended practice in the safe handling of plutonium in laboratories and plants. G. J. Appleton & H. J. Dunster. AERE Harwell. **Report AHSB(RP) R 6.** 46 pp. Available from HMSO 7*s*.

The treatment of thermal neutron scattering law data. P. A. Egelstaff. AERE Harwell. **Report AERE R 3622.** 35 pp. Available from HMSO 5*s*.

High temperature X-ray diffraction studies. Part 2 uranium monocarbide and uranium dicarbide. I. F. Ferguson, R. S. Street & T. N. Waters. AERE Harwell. **Report AERE M 819.** 8 pp. Available from HMSO 1*s* 9*d*.

Langmuir probe techniques in intense discharges. H. W. Jones and P. A. H. Saunders. AERE Harwell. **Report AERE R 3611.** 33 pp. Available from HMSO 5*s*.

' Nuclear Power ' INFORMATION

The papers reviewed here represent only a very small selection of those acquired and read by *Nuclear Power*. If you hear of a paper and have difficulty in obtaining a copy, write or telephone *Nuclear Power* Information Bureau, 77-79 Charlotte Street, London W1, MUSeum 8252.

Programmes extended at BWRA

new engineering laboratory opened

The enrolment of 60 new research and advisory workers and the recent completion of the 21,000 ft² Engineering Laboratory have enabled existing lines of research to be expanded and some new lines to be developed, says the 16th Annual Report of the British Welding Research Association.

It states that emphasis has been placed on the study of heat effected zone cracking in heat-resisting steels. Other investigations on the efficiency of gas shielding and the measurement of hydrogen absorption in the weld pool have been made, as well as development trials of bare wire CO_2 shielded welding. Nearly all aspects of resistance welding can be examined; equipment has been placed at the disposal of the Association by member firms.

Other work done by the Association includes development of a new design procedure for the reinforcement of nozzles and openings in pressure vessels; the use of low alloy steels for pressure vessels; a prototype welding service; and a welding design advisory service.

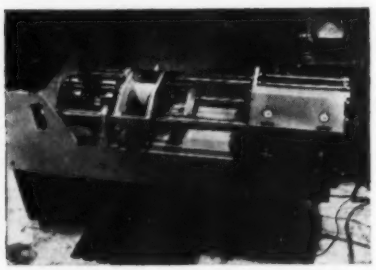
A few examples of work being done are given below.

Friction welding

This process consists of placing the ends of two bars in contact and rotating one of them till enough heat is generated to effect a weld. The machine recently developed at the BWRA is said to be the first in the country though they are in production use in the USSR and British Patents were taken out as early as 1941.

The machine can weld up to 1 in² mild steel and is powered by a 10 hp motor at 950 rev/min. Axial force is provided by a 12-in dia. double acting air cylinder and upset and friction forces to a maximum of five tons provided by a 100 lbf/in² air line.

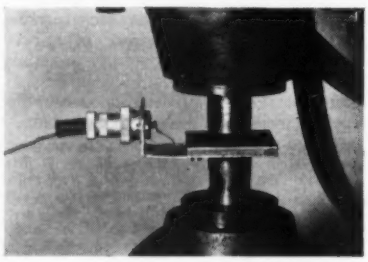
The major mechanical problem is arresting the revolving head. The simplest and cheapest method is to allow the stationary shaft to accelerate up to the speed of the revolving shaft. At a preset 'burn-off' distance a solenoid-operated latch releases a cantilever, holding a torque arm in place, from its stop position. This torque arm prevents the stationary shaft from rotating at the beginning of the welding operation. The solenoid control circuit also operates the air valves and trips the motor.



Sufficient heat is generated when two bars, one fixed the other rotating, are brought together under pressure to weld them together

Spot weld temperature

Little is understood of the way in which spot welds are formed. With hardenable steels, post-weld heat treatment is needed to give a ductile weld. The heat treatment is usually carried out by the machine but machine settings are largely a matter of trial and error.



Efforts are being made to discover the temperature distribution in spot welding; a thermocouple can be seen here coming from between two sheets in the welding machine

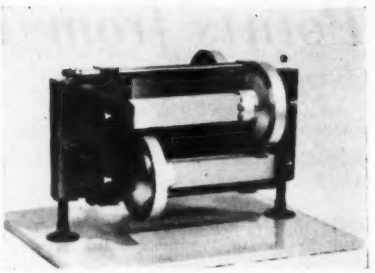
Fine wire alumina thermocouples, mounted either between the two sheets being welded or vertically in the electrode, are being used in an attempt to measure the temperature cycle during spot welding. High speed recording is necessary and these are shown either on an oscilloscope or a high speed ultra-violet galvanometer recorder.

Some problems have still to be overcome; for instance, it has been found that some of the thermocouples melted inside the weld nugget indicating a temperature of at least 2000°C.

Tensile test rig

Supplementing the 700- and 2000-ton capacity rigs at BWRA, this new machine is designed to produce fractures in alloy steel plates up to 4 in thick and mild steel plates up to 6 in thick. Its capacity is 4000 tons.

It will be made of 6-in thick low alloy steel plate of 25 tonf/in² yield and electroslag welding will be used in its construction and for preparation of specimens. The loading will be by hydraulic capsule as in the 2000-ton machine but with the number reduced from twelve to four. A longer working stroke is provided and the operating pressure is 800 lbf/in². The total weight is of the order of five tons.



Model of the 4000-ton capacity brittle fracture tensile test rig to be used for fracturing plates up to 6 in thick

Rigs of this capacity are also being prepared for the UKAEA, and for Ghent University under the sponsorship of Euratom. Interest has also been shown by the Paton Institute at Kiev.

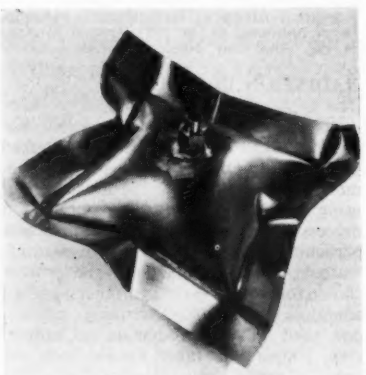
Induced stresses

Where the fatigue strength of a welded joint is determined by the presence of a localized notch, for instance, the discontinuous longitudinal welds used for joining of flanges at right angles or for attaching girder stiffeners and gussets, large increases of fatigue strength can be obtained by applying residual compressive stresses at the discontinuities. This can be done either by spot heating with an oxyacetylene torch or by local compression of the specimen to produce local plastic flow.

The current programme is aimed at application of the method to more complex assemblies and to find a suitable way of applying the treatment under adequate control.

Continuous seam welding

The conventional method of seam welding where two sheets of metal are passed between a pair of copper electrodes, and an intermittent low voltage high current produces overlapping welds, is unsuitable for highly alloyed stainless steels. These



Pillow test to determine the pressure tightness of seam welds made with continuous a.c. current. Two plates are welded on four sides and inflated to failure; this particular specimen withstood a pressure of 1400 lbf/in²

interrupted welds are liable to crack. Research has shown that continuous a.c. current eliminates the cracking and it also appears that the welding conditions are less critical.

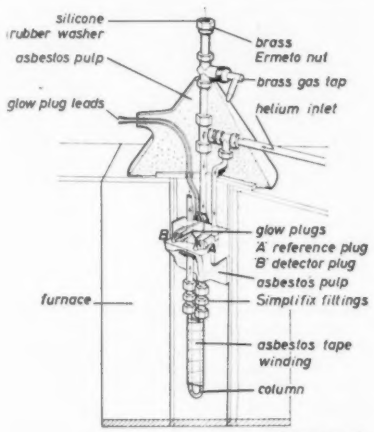
Thorium fuel

feasible for BWR's

Studies by US General Electric, reported at the 6th Annual Nuclear Congress at Rome, indicate the feasibility of U-235/Th-232 fuels for BWR's and also show a number of advantages. The conversion of a reactor originally designed for U-238 fertile material to use of Th-232 fuel may be made by changing the fuel rod size and thus altering the water-to-fuel ratio. The studies have also included examination of U-235, mixed U-238/Th-232 fuels with the fertile isotopes mixed within each fuel rod.

Little consideration has hitherto been given to the latter type of fuel. Preliminary analysis shows that the chemical processing problems are not so great as to preclude its use.

The available technical and economic information does not allow a conclusive choice to be made between Th-232 and U-238. However, the report suggests that new reactors should contain provisions for including either of these fertile isotopes.



'Nuclear Power'

GAS CHROMATOGRAPH This apparatus constructed from readily available components is suitable for the routine analysis of polyphenyls. A temperature of 425° C is maintained using a laboratory furnace on end. The U-tube column is made from ¼ in o.d. stainless steel about 2 ft long packed with chromatographic alumina. Novel hot wire detectors, model aircraft glow plugs, are used. The sample injection system is suitable for use with both solid and semi-liquid samples. The detector output is of the order of 2·0 mV/mg for biphenyl and lower for higher polyphenyls. The detector circuit is a straightforward Wheatstone network, the out-of-balance voltage being fed to Honeywell Brown 2·5 mV recorder. Satisfactory sensitivity is obtained with samples of about 15 mg

(A simple apparatus for the gas chromatography of polyphenyls. R. W. Wilkinson and J. A. Winter. AERE Harwell. Report AERE M 820. Available from HMSO 2s. 6d.)

Calder graphite

examining radiation effect

Inspection of graphite after 4½ years' irradiation has confirmed earlier predictions of Wigner growth. To facilitate measurement a special cutting tool 3 in dia. × 2 ft 6 in long was developed by the Langham Engineering Co. Attached to the end of 50 ft of hose carrying the pneumatic, hydraulic and electric circuits, the device is lowered down a control rod channel to the required point in the reactor core. Jacks are extended to clamp it against the sides of the channel. The cutter head then automatically cuts a cylindrical specimen from the graphite

The cutter head has been withdrawn from the reactor core and a test specimen is being extracted

which is then carried back into the body of the machine.

During the cutting operation, a coolant and dust exhaust system blows CO_2 on to the cutters to extract the graphite dust; an electrical signalling system continuously reports progress. A separate hydraulic system allows the cutting head to be retracted independently of the normal drive in an emergency.

On-load refuelling

experiments at Calder Hall

The effects of thermal cycling and of loading at full power have been tested on Calder Hall fuel elements. The experiments were concerned with the effect on the uranium and subsequent metallurgical and radiographic examination of the elements showed no significant effects in either of the tests.

On-load conditions were simulated by arranging the gas flow through a channel so that the heat production from the element as it entered the channel together with heat from surrounding channels gave the required temperature change. Elements were inserted at the correct speed by means of a spare control rod mechanism which also held the element at the required position.

In the thermal cycling tests, two control rods were oscillated up and down the core for about 13,000 cycles and elements from neighbouring channels examined.

Precision welding

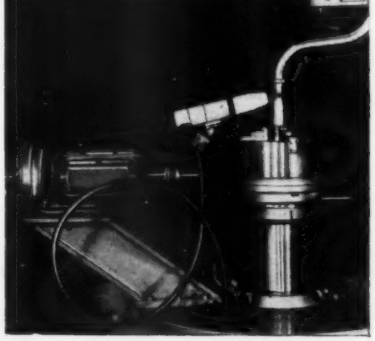
new 'orbital' method

An automatic method of welding end fittings to bent tubes of small diameter by rotating the weld head rather than the workpiece has been developed by Palmer Aero Products Ltd (a subsidiary of BTR Industries Ltd). Once set up, consistent welds can be reproduced by push-button operation.

Where tube assemblies are complex and the shapes need to be reproduced accurately to close tolerances tubes are bent with discard lengths and then cut to length. Welding is preferred to conventional brazing because of the generally higher strength at elevated temperatures, and greater corrosion resistance and fatigue strength. Manual welding has disadvantages because uneven bead contours can give rise to turbulence and alter flow characteristics from one tube to another. These contours are also a focal point for stress patterns—serious when the tube is subject to cyclic variations due to temperature cycling, pulse pressures and vibration.

Welding is by standard argon-arc torch supplied with argon, hydrogen, water and electrical power. Argon is also passed up through the workpiece and there is an external gas shield round the weld area. The 2% hydrogen added to the argon reduces oxidation, increases fluidity of the melt giving better penetration, and increases arc volts giving a deeper narrower weld for the same current setting and arc length. It also reduces the number of tungsten inclusions from the electrode.

The pipe to be welded passes through a hollow chuck. It fits into a socket in a prepared fitting which has an integral external projection of filler metal above the actual joint. The weld operation is



Close up of the orbital welding head for joining end fittings to bent tubes automatically, the external gas shroud is not shown

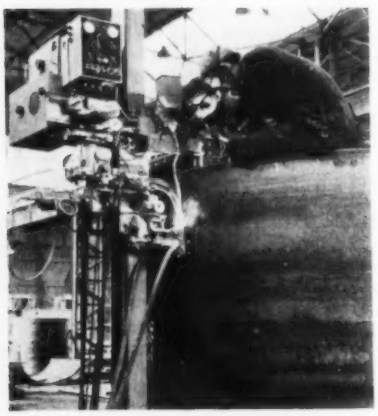
controlled automatically once a satisfactory set of weld conditions has been established—that is, combination of arc dwell time, arc current, arc current delay period, weld cooling time, etc. The control circuit was designed by F. Hirschman Ltd. It has been found that a welding speed of

20 in/min is necessary to prevent gravity fall of the bead and two passes are required for complete penetration. This has the added advantage of grain refining the weldment. So far the method has been used for niobium stabilized austenitic stainless steel. It is reported to be satisfactory for Nimonic alloys and titanium. On a 0·050 in tube the reinforcement bead can be controlled to 0·025 in and the penetration weld is 0·004-0·005 in.

Vertical welding

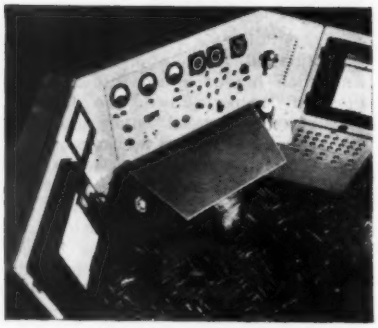
new automatic machines

A version of the electro-slag welding process, known as 'Subarc' has been developed by the British Oxygen Co. Two machines have been in use for the past four months welding 1⅞in plates for the legs of an off-shore drilling rig. The welding speed for plates this thick is 7–8 in/min and about 70 lb of electrode is consumed for an 8-ft weld, with the plates 1¼ in apart. What is new about these



Automatic electro-slag welding machine joining 1⅞ in plates

machines is the differential thermocouple system controlling the movement of the welding head and cooling shoes. With both thermocouples in the weld pool there will be no difference in temperature; the carriage then moves up until the upper thermocouple is in the slag and at a lower temperature.



INSTRUMENTATION AT DOUNREAY A new control console for the Dounreay Materials Testing Reactor has been installed recently by James Scott (Electronic Engineering) Ltd. The centre panel carries all controls for start-up, shut-down, scram-signalling and control arm position indicators and controls. Reactor parameters are also displayed here. The large panel (left) shows the heavy water differential temperature and has a 24-way annunciator panel for fault conditions. Reactor power is shown on the right-hand panel.

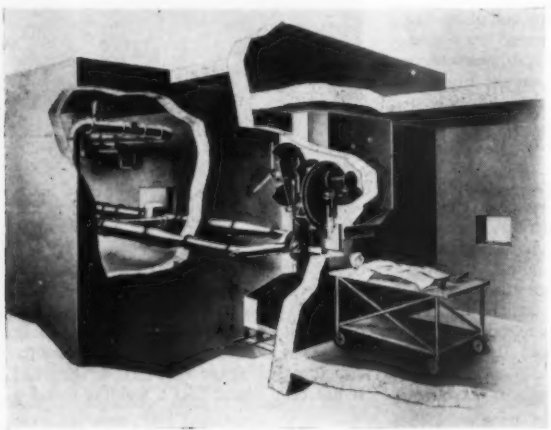
Slow neutron separation

new therapeutic tool

A new AMF concept for separating slow neutrons out of the broad spectrum of radiation from a reactor is likely to be of great value in the field of medical therapy. The advantages of slow neutrons have been known for some time.

'Syftor' (Synchro-screened Fast Reactor) uses the 'diffusion-time discrimination' principle, based on a pulsing technique whereby radiation is emitted from the reactor core in a series of discrete pulses. The pulses are passed through a tank of heavy water which produces the diffusion-time resolution. The new concept consists of a fast-pulsed reactor, an external moderator, and a mechanical arrangement that pulses and screens the core in synchronism.

The first 'Syftor' design is expected to produce an integrated flux of 10^{15}nvt at the dose point in 100 minutes, while non-thermal neutrons and gammas are held to 100 r. Modifications could produce the same flux in as little as two minutes.



Developed for neutron capture therapy, AMF's 'Syftor' screens out gamma rays and fast neutrons, and permits a new method of radiological treatment and diagnostics

IN BRIEF

COMPUTER TECHNOLOGY STRETCHED Under development since 1955, the world's most powerful computer, Stretch, built by IBM to Los Alamos specifications, has been delivered to the LASL and is undergoing tests. A continuous flow of more than one million words a second is possible, with a peak flow rate capability of around three million words a second. Nearly 1¼ million digits of information can be transferred from the magnetic disk file to the core storage unit.

NEW ELEMENT DISCOVERED Using a heavy ion linear accelerator scientists at the Lawrence Radiation Laboratory, Berkeley, have discovered an isotope of element 103. It has a half life of about 8s. and its maximum atomic weight is thought to be 257.

NEW NBS LABORATORIES Work has started on the $104m research facility which will permit complete relocation of the US National Bureau of Standards from NW Washington to Montgomery County. The first building, an engineering mechanics laboratory, will house dead weight testing machines of 1,000,000, 100,000 and 300,000 lbs capacity, a gravity chamber, and an Emery horizontal testing machine. Later work will include a radiation physics laboratory (including a linear accelerator) and a reactor.

HIGH MAGNETIC FIELDS Using a special solenoid magnet, formed from 135 ft of copper ribbon 6 in wide tapering to 1¼ in at one end, the Massachusetts Institute of Technology has generated a continuous magnetic field of over 126,000 gauss. The magnet, made by High Voltage, was operated at a current level of 10,000 A and cooled by water at 320 gal/min.

CARBON DIOXIDE POLYMERS Likely to have important consequences on any work with CO_2 under pressure is the recent discovery, made at the UKAEA, Capenhurst, that the gas probably forms polymers. The intensities of the polymeric ions change rapidly with reservoir pressure.

EPOXY RESIN FOR HINKLEY The 2000 or so collection skips to be used at Hinkley Point for the disposal of spent fuel elements are being made from mild steel coated to 0·015 in thick with Adcora SP solventless epoxide coating.

HYDROGEN DETECTION The NIRNS 50 MeV proton linear accelerator is to be fitted with two Mine Safety combustible gas alarms for the detection of hydrogen in air concentrations exceeding 2%.

DIRECT GENERATION A small 5 W thermoelectric generator that converts gas heat directly into electricity, for installation in gas appliances, is the target of a joint programme launched by General Dynamics and the American Gas Association. Also using gas, a mixture of propane and air, is the flame-heated thermionic generator developed by Atomics International, which has had its first successful test. The flame heats one of two electrodes to 2800°F and the electrons produced jump the small gap to the cooler electrode, thereby producing an electric current.

'Nuclear Power' INFORMATION

For further information on any item write or telephone 'Nuclear Power' Information Bureau, 77-79 Charlotte Street, London W1, MUSeum 8252.

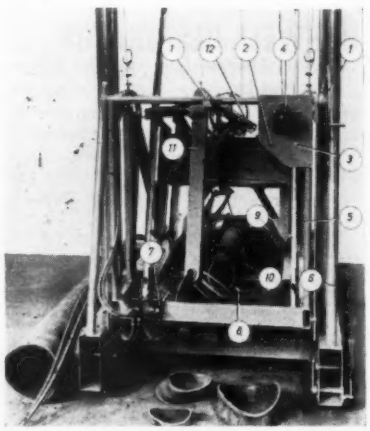
New Product Survey

EQUIPMENT · INSTRUMENTS · MATERIALS

TUBE PREPARATION

automic flame-cutter

Economies over other methods of tube preparation are claimed by General Precision for their 'Tubefile' system, a versatile automic flame-cutting machine that produces profiles on steel tubes required to saddle other tubes. The machine can be set up quickly, given the angle of intersection of axis of the main barrel and branch, the external diameter of the barrel and the internal diameter of the branch.



General Precision's 'Tubefile 18' is intended for profiling branch tubes up to 18 in external diameter

1 intersecting angle adjustment and clamp 2 start button 3 on-off switch 4 'Variac' cutting speed control 5 intersection angle scale 6 tube centering lever 7 flame gas controls 8 flame cutting head 9 halving frame 10 branch centering jaws 11 off-set adjustment 12 branch diameter scale

All settings, which are indicated on three scales, are effected by operating controls. There are other adjustments for notch angle, offset and distance of the cutter from the profiled branch.

Cutting is done by moving the cutting head around the tube, the tube being held stationary. The traversing speed of the flame cutter may be set as required, it may also be adjusted during any cut to give the maximum speed for the thickness of metal being processed.

★ 208

NEUTRON FLUX COUNTER

boron lined, gas filled

Plessey Nucleonics has introduced a PNI 1077 series of proportional counters for use at low power levels in the installed neutron flux measuring channels of reactors. Constructed of very high purity aluminium with a 94% enriched boron lining and a gas filling of 10 cmHg of argon and 2 cmHg of methane, they permit immediate operation after long periods in high neutron fluxes. Ceramic-to-metal seals and ceramic insulators are employed to provide a robust counter suitable for plant use. The counter operates at relatively low voltages and a gas multiplication of 50 is obtained at about 750V. Higher gas multiplication may be used if required.

Irradiation of the counter in a high neutron flux produces a background count similar to that obtained in high gamma fluxes. This may be rejected by operating the counter at an EHT value below that at which the pile up of residual activity and gamma pulses is sufficient to pass the discriminator threshold chosen. In practice, after long irradiation in a thermal flux of 10^{10} n/cm²s, this background can be rejected within ten minutes of the removal of the neutron flux. In most cases, therefore, where the counter is used for the low level neutron flux instrumentation, no retraction mechanism is necessary to remove the counter once full power is reached.

The counter is also very resistant to long term radiation damage since, unlike BF_3, the counting gas is not affected by irradiation and the counting characteristics remain unchanged over a total dose of more than 10^{18} n/cm². Three types are currently available in lengths 14·5 in, 22·5 in and 30·5 in, the diameter in each case being 1in.

★ 209

METAL TREATMENT

convertible welder-cutter

A new type of blowpipe, marketed by Suffolk Iron Foundry, can be used either as a cutting torch or a welding torch by a simple change of nozzle, without any conversion at the bottom of the shank. The Double Duty Demon weighs only 1¼ lb and it cuts sheet metal and steel plate up to 2 in thick, and welds steel up to ¼ in thick.

Suffolk Iron Foundry's new blowpipe both welds and cuts, requiring only a change of nozzle

The handle to the torch is constructed of non-metallic composition with a non-slip fluted grip. Three welding and two cutting nozzles are supplied suitable for handling most of the requirements of everyday welding and cutting.

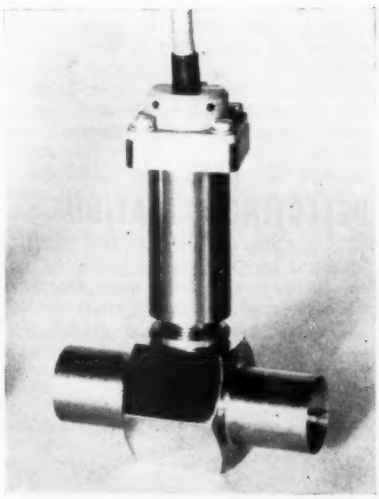
★ 210

LIQUID FLOWMETER

high temperature use

Developed for the UK AEA, Winfrith, and ordered for the Euratom Petten centre and by Rolls-Royce, Meterflow's new impeller-type flowmeter is primarily designed for use on heat transfer systems employing either high temperature water or terphenyl.

In its present form it has a maximum temperature rating of 400°C; linear flow ranges of 0·3 to 3 gal/min, 1 to 8 gal/min, and 3 to 25 gal/min are currently available. Pressure drop in all cases is 5 lbf/in² at maximum flow range. Overall linearity is better than ±1% with repeatability better than 0·2%. Maximum internal pressure is 3000 lbf/in² and the output frequency at maximum flow is 1000 c/s.



This new flowmeter, developed for the UKAEA is suitable for use on heat transfer systems up to 400°C

The general construction of the flowmeter is of stainless steel with silver graphite bearings (98% silver).

★ 211

SUPERHEATER STEEL

new ferritic type

A new grade 12% Cr-steel, HT9, containing Ni, Mo, V and W, for use at higher steam temperatures and pressures, is to be produced by Sandvik. Whilst only a few of the steels have so far been made into tubes, proven properties indicate a promising potential. This type of steel has

already been introduced by Mannesmann, in Germany, for superheater tubes at temperatures up to 600°C.

TABLE 1

TEST TEMP., °C	lbf/in²	STRESS RUPTURE STRENGTH σB/10,000h lbf/in²	σs/100,000h lbf/in²
200	63,000		
300	57,000		
400	51,000		
450	47,000		
500	43,000	40,000	33,000
550		28,000	21,000
600		14,000	9,000

Whilst creep rate tests are still too limited to permit a precise statement of value for creep strength, creep rupture values in most instances are sufficient for determining accurately the wall thickness of the tubes (see Table 1).

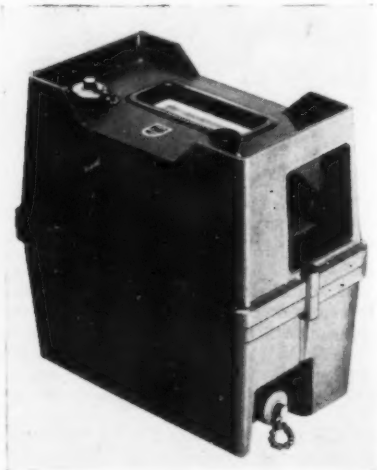
Because of the high content of alloying elements, HT9 can be fully hardened even by air cooling from austenizing temperature, although rather long tempering times at high temperature are required to harden it below about 300H_v. Hot working, like bending and forming, can be carried out at 1100–850°C. After bending over a small radius, the material is stress-relieved most efficiently at 700–750°C. The steel can be welded by arc, argon-arc, and flash welding.

★ 212

DETECTING RADIATION

battery-operated meter

Marketed by Research and Control is the new Philips contamination meter, type PW 4015, designed for the measurement of gamma dose rates and for the detection of beta radiation.



The Philips PW 4015 gamma and beta contamination meter operates either from standard 1·5 V cells or power supply. It is rugged and waterproof

For gamma measurement are two built-in G.M. tubes, types 18503 and 18509, with a socket for external probes. The measuring range, in linear scale, is 0–1000 mr/h, 0–100 mr/h, and 0–10 mr/h. These detectors are energy compensated; for mono-energetic radiation in the range of from 80 keV to 1·2 MeV the energy dependency is within ±25% of true dose rate. Beta radiation is detected by using external probes.

There are only two controls: an 8-position function switch that is linked mechanically to the separate scales of the meter, and a non-locking push-button for scale illumination.

★ 213

ELECTRONIC TESTER

automatic measurement

For application in the fields of computers and electronics, and marketed in the UK by Metrix, is the Lavoie Robotester LA-303, an automatic tape programmed measuring instrument. With it any of 250 circuit points can be selected for the measurement of resistance, polarized d.c. or a.c. voltage, insulation resistance, and impedance.

The new Lavoie LA-303 electronic tester is automatic and tape programmed

The range of voltage measurements can be from 0·5 to 500V, the resistance range is from 1Ω to 9·99 MΩ with a selected tolerance of 1%, 5%, 10% or 20% nominal. Impedances in the range of 50Ω to 100 kΩ are measured at programmed frequencies of 159 c/s, 1·59 kc/s or 15·9 kc/s. Between 60 and a 100 tests per minute indicate wiring or assembly failures by flashing light indicators.

★ 214

CATHODE DISPLAY

precision components

Special cathode ray tube accessories for use in precision display applications are now being produced by General Dynamics Electronics. Among components available are deflection yokes, convergence coils, and magnetic shields.

The deflexion yokes, with distortion-free linearity, operate from constant current sources to provide horizontal and vertical electron beam deflexion in a cathode ray tube. Stabilization times of 10 to 20 μs are possible.

The convergence coils are solenoids producing a uniform magnetic field which maintains the magnetic beam in a cathode ray tube exactly to the tube axis. Magnetic shields, basically thin laminar metallic enclosures, are available for various bulb geometries and sizes from 5 in to 21 in.

★ 215

MECHANICAL SEAL

high pressure operation

Sealol Ltd has introduced a face-type seal that can withstand temperatures up to 1500°F and pressures over 1000 lbf/in². Other seals to operate at pressures over 2000 lbf/in² can be specially produced, if necessary.

The unit incorporates a welded metallic bellows consisting of a series of precision washer-like plates welded to form convolutions. These plates can be of any weldable material, including stainless steel, making the unit suitable for handling corrosive liquids.

★ 216

HARWELL RESPIRATOR

interchangeable filters

A special half-face respirator, developed by Mine Safety Appliances and designed for use at the UK AERE, is suitable for a wide range of industrial applications. Three types of filter element are available and these are interchangeable to suit the particular hazard.

The type F filter gives protection against dusts not significantly more toxic than lead and covers nuisance dusts, toxic and fibrosis producing dusts, and mists. Type S filters are for dusts, mists and metal fumes, and extend the protection afforded by the Comfo respirator into a range of finer particle sizes. Type H ultra-filters have been developed for toxic aerosols and for extremely fine particles, and will filter the finest smokes as well as highly toxic particles, including radioactive dusts. They are also effective against bacteria and viruses.

Two compact filter holders are mounted one on each side of the respirator facepiece.

Large numbers of the M.S.A. Comfo respirator are being supplied to Harwell. Filter elements are available to absorb both radioactive and non-radioactive vapours

Made of a special new compound the face-piece is both durable and comfortable to wear. Being soft, it provides a dependable air-tight seal with the wearer's face and will not harden or assume distorted shapes. Positive-action exhalation valves offer little resistance to air-flow and permit normal breathing. A four-piece adjustable headband is fitted.

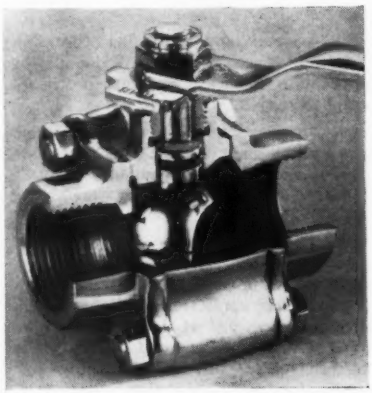
★ 217

BALL VALVE

range extended

The UK Worcester Valve Company has augmented its range of ball valves, introduced last year, with 3 in, 4 in and 6 in sizes. One of the outstanding features of this type of valve is that it acts both as a valve and as a union. Detachable pipe ends replace the companion flanges of other type valves. Maintenance is simple, by removing the four bolts the entire centre section lifts right out.

Because of the many various combinations of seats, O-rings (Buna-N, Nylon or p.t.f.e.) and body materials (bronze, carbon steel, stainless steel and aluminium)



The Worcester ball valve is easy to install and service. With the centre section quickly removed, seats and O-rings are simple to replace

it can handle almost any media within the pressure-temperature limitations of the sealing materials.

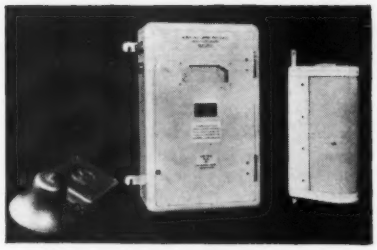
The makers claim, over other valves, about ¼ saving in weight, greater life expectancy through the less damaging wiping action of the seats against the ball, and positive shut-off even after many thousands of cycles.

★ 218

RADIATION MONITOR

visual and aural alarms

Originally designed for the UK AERE, Redcliffe's radiation monitor and alarm assembly, type 1641C, is an a.c. mains operated dose-rate instrument for the detection of gamma radiation. The equipment is designed for wall mounting and comprises a detector and control unit, a lamp unit, and a mains operated alarm bell. Apart from continuous indication by meter of radiation level, two alarm levels are provided that operate coloured lamps and a warning bell which rings



Redcliffe Radio's new AERE type 1641C gamma radiation monitor comprises a wall-mounted detector and control unit, a lamp unit, and a mains operated alarm bell

intermittently or continuously according to the alarm level. Provision is also made for operating remote lamp and annunciator systems.

The control unit houses the ion chamber, electrometer unit, control circuits, radiation level meter, and power supply unit. The aluminium ion chamber is 3·5 litres in volume and contains a low energy priming source. In addition, a calibrated Sr-90 radioactive test source, contained in a small pivoted housing, can be rotated against a spring to bring the source in front of an aperture in the ion chamber. This enables rapid checking of the correct functioning and calibration of the equipment. The housing is spring-loaded to its non-active position.

The output of the electrometer unit is fed to a moving coil meter which enables radiation levels to be read directly. A blade on the instrument pointer also intercepts the light to two preset phototransistors which operate the alarm relays. Normal settings for these are 30 mr/h for the first alarm level and 285 mr/h for the second alarm level.

★ 219

IN BRIEF

• **Decade counting units.** For use with any form of electronic counter, the visual decade counting unit introduced by Winston Electronics, counts impulses up to a maximum rate of 40,000 per second. The circuit is basically made up of four binary counter stages and two internal feedback circuits between stages cause the counter to advance six counts without recording, thereby allowing the counter to recycle after ten input pulses.

★ 220

• **Vacuum thermobalance.** Stanton have developed a new 'Massflow' thermobalance that provides a continuous record of weight changes of a sample in a furnace in a pressure range 10^{-4} Torr to 700 g/cm³ as a function of time and temperature. Materials can be examined in pure gas atmospheres.

★ 221

• **Rotary vacuum pump.** A new design of N.G.N. two-stage pumps gives gas ultimate pressures of better than 10^{-4} mmHg without gas ballast and better than 10^{-3} mmHg with full gas ballast flow (i.e. 10% of pump capacity). The gas ballast flow is controlled by a needle valve which may be locked in any position.

★ 222

• **Hardness tester.** Marketed in the UK by Metallurgical Services, the portable Newage Tester relies on hand pressing a pre-loaded diamond indenter towards the specimen. This movement compresses a diaphragm and hydraulically forces fluid into a capillary tube. The final position of the fluid indicates direct hardness value.

★ 223

• **Rapid steel analysis.** Hilger & Watts' new Polyvac-12 direct reading vacuum spectrograph is intended for the rapid automatic analysis of carbon, phosphorus, sulphur and other elements in steel. It consists of a source unit, a polychromator accommodating from 12 to 20 EMI photomultiplier tubes, a console and a vacuum pump.

★ 224

• **Pneumatic control.** For pneumatic control systems are the two new AEI units, type 59D for direct, and type 59R for inverse derivative, action. Operating at a supply pressure of 251 lbf/in², the units have a derivative time adjustment of from 0·2–20 min. Input and output pressure ranges are 3–151 lbf/in² and maximum operating temperature is 200°F. An additional unit, using a wool filter type cartridge, is the combined filter regulator 91F, that removes oil fog and moisture from instrument supply air as well as regulating it without flutter or oscillation.

★ 225

• **Stop valves.** Designed for use in either pneumatic or hydraulic circuits, or with non-corrosive gases, Simplifix Type 60 gunmetal stop valves are now available in ¼ in, ½ in, ¾ in, and 1 in sizes. Spindles are made from manganese bronze and have a fine thread to facilitate opening and closing.

★ 226

• **Cathode ray tubes.** The M-O Valve range of double-gun helical post deflexion acceleration cathode ray tubes has been extended by the addition of a 5 in dia. tube, type 1300F, for use in general purpose oscilloscopes where two independent signals are displayed on a common time base.

★ 227

• **Tungsten-carbide cutter.** Hoy Carbides have developed a fine grain 'Hoybide' CW grade tunsten carbide that will machine the more difficult alloys at greater speed, giving a better finish and more components per regrind than any other grades of carbide previously available.

★ 228

• **Disposable clothing.** A low-cost range of disposable fire-resistant and water repellent clothing, made of material like woven cloth, has been introduced by General Scientific Equipment. Shirts, pants, laboratory coats, hats, boots, aprons and gowns are available.

★ 229

• **Elapsed time meter.** Suitable for application to pumps, ventilating and heating systems, X-ray transmitting tubes, etc., is the new English Electric elapsed time meter. It can register up to 9999·9h in steps of 0·1 h.

★ 230

• **Flow indicator.** Walker Crosweller have extended their range of Arkon ball flow indicators to a 1 in size. The starting flow on liquid is ½ gal/min, on gas 2 ft³/min; if the flow stops the ball drops out of sight.

★ 231

★ *For further information on any item, circle the appropriate number on the reply card facing page* 108.

STUDENTS' NOTEBOOK

GROUNDWORK—Teaching

What are the welding processes available to industry?

As Mr R. G. Burt points out in his review (see this issue) the use of welding for an ever-increasing range of materials is rapidly expanding. It has made a significant contribution to many of the outstanding developments in the nuclear and electronic industries. New and improved processes, equipment and techniques are constantly being introduced and the range available to the fabricator is now very wide and possibly bewildering.

Apart from a careful assessment of process specifications, successful welding application requires a sound knowledge of metallurgical principles covering an understanding of the problems of oxidation, the microstructural changes that take place in the weld and base metals, and the resultant mechanical properties such as strength ductility, notch toughness, fatigue strength, corrosion resistance and soundness. A brief description of welding processes is given below.

GAS WELDING

Coalescence of materials is effected by heating with a gas flame. A filler metal may be used where required.

Air-acetylene. The gas flame is obtained from the combustion of acetylene with air (*No pressure*). **Oxy-acetylene.** The gas flame is obtained by the combustion of acetylene with oxygen. (*With or without pressure*). A very versatile process, suitable often where metallic arc welding is not, but it is slower for thicknesses greater than $\frac{1}{8}$ in. **Oxy-hydrogen.** The gas flame is obtained by the combustion of hydrogen with oxygen. (*No pressure*). **Pressure gas.** Coalescence of materials is produced simultaneously over the entire area of abutting surfaces by heat from a fuel gas/hydrogen flame. No filler metal is required. (*With pressure*).

ARC WELDING

Coalescence is effected by the heat of the arc, which is a low voltage, high current discharge, formed between the work metal—connected to one pole of an electrical system—and an electrode, held in a suitable holder, connected to the other pole. The electrical system can be either d.c. or a.c.

SHIELDED PROCESSES

Carbon-arc. A carbon electrode is used and, as there is no metal transfer through the arc, filler metal has to be added from separate filler rods. The high temperature generated permits high welding speeds. (*With or without pressure*). **Inert-gas carbon-arc.** A carbon electrode is used and the work is shielded by helium or argon. (*With or without pressure*). **Shielded metal-arc.** A covered metal electrode is used and shielding derives from the decomposition of the electrode covering. The filler metal also comes from the electrode. (*No pressure*). **Inert-gas metal-arc.** Helium or argon is used to shield the work metal. Argon arc employs a non-consumable tungsten electrode; a process known as the self-adjustable arc, or Sigma welding, uses a thin consumable electrode. (*With or without pressure*). **Impregnated-tape metal-arc.** Impregnated tape wrapped around the electrode decomposes as it is fed to the arc acting as a shield. (*No pressure*). **Atomic-hydrogen.** An arc is struck between two tungsten electrodes in an atmosphere of hydrogen. The outer flame of burning hydrogen protects the metals from oxidation. (*With or without pressure*). **Submerged-arc.** Bare metal electrodes are used and the welding is shielded by a blanket of granular fusible material. The filler metal comes from the electrode or supplementary welding rod. (*No pressure*). **Shielded stud.** The arc is drawn between a metal stud and the other work piece. When both surfaces are sufficiently heated they are brought together under pressure, with helium or argon used for shielding.

Carbon-arc, twin carbon-arc, bare metal-arc, and stud welding processes are also used without shielding.

Electro-slag welding. This is a development of the submerged-arc process but in this case the heat is put into the slag, that forms on the weld from the melted flux, creating an entrapped and controlled molten pool which in turn fuses the electrode wires. This process is suitable for thick plates.

RESISTANCE WELDING

Coalescence is produced by the heat generated from the resistance of the parent metals to the flow of electric current in a circuit of which the metals form part. No filler metal is required and the weld is consolidated under pressure. **Spot.** The parent metals are held together by electrodes, the size and contour of which limit the size and shape of the weld. **Seam.** Using circular electrodes, the resulting weld consists of a series of overlapping spot welds along the joint made by rotating the electrodes. **Projection.** The electrodes take the form of large blocks covering the weld area. By means of projections or embossments, localized welds are obtained. **Flash-butt.** The entire area of abutting surfaces coalesces simultaneously, when an arc is produced between the ends of workpieces, brought together under pressure after heating. With resistance-butt welding pressure is applied before and during the heating period producing a bulbous shaped weld. **Percussion.** An arc, produced by a rapid discharge of stored electrical energy, heats the metals; pressure is applied percussively both during and immediately after the discharge.

OTHER WELDING PROCESSES

Thermit welding. Heat is obtained by the formation of molten metal, following the chemical reaction of iron oxide and aluminium powder after it is ignited. In the pressure application the liquid metal does not supply the weld filler metal, as in the non-pressure process. **Induction welding.** Coalescence is produced from the resistance of two surfaces to the flow of induced electric current. **Forge welding.** Coalescence is effected by heating the working parts in a furnace and applying pressure of blows, by hammer, die or by means of rolls. **Ultrasonic welding.** Components are subjected to ultrasonic vibration under pressure, the useful frequency range being 10 kc to nearly 100 kc. This is a useful process where the application of heat is undesirable. **Electron beam welding.** Heat is generated by beams of electrons accelerated by high voltage. **Brazing.** This process is not strictly speaking a welding one, metals are joined by the addition of a non-ferrous molten filler metal that has a melting point below that of the base metals. This metal is not merely deposited along the edges, as for a weld, it is drawn by capillary action right through the mating joint surfaces. Heating can be attained by using torch gas flame, twin-carbon arc, furnace, induction, resistance, molten dip, heated blocks, or molten filler methods.

NEWS

- The first single source book on graduate physics research, covering 800 doctoral theses from US universities accepted between 1861-1959, entitled 'Dissertations in Physics', has been published by the Stanford University Press.
- Since it started in January 1957, the Calder Operation School has trained 532 students, 30% of whom came from overseas.
- Sixth among the large PACE installations to go to European educational establishments, is the Electronic Associates' 231R expanded computer, purchased by the Eindhoven Institute of Technology, in the Netherlands.
- A two weeks course, the first of its kind, has been organized by Oak Ridge for the application of nuclear methods to oceanography research.
- A summer school for science masters was recently held at the Calder Operation School. Basic reactor techniques, radiation protection and fuel processing were among the subjects.
- Visiting Europe on one-year research fellowships are two Argonne scientists. Dr W. A. Chupka will research into mass spectrometer applications to high temperature chemistry at Mainz, Bonn and Stockholm. Dr D. Okrent, an authority on fast reactor physics, will study high temperature materials at Cambridge.

UK COURSES

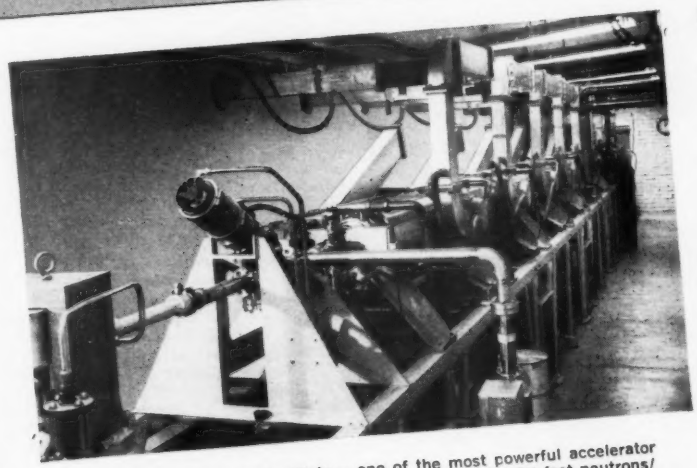
Borough Polytechnic, London Nucleonic techniques and measurements, part time course: Friday afternoon and evening beginning October 6, or Tuesday morning and afternoon beginning October 3; full-time course: 2 months beginning October 16, Fee: £2 10s or £15. Nuclear power: 23 evening lectures (weekly) beginning October 5, Fee: £2 10s. Nucleonic circuitry: 10 evening lectures (weekly) beginning October 4, Fee: 25s. Nuclear particle techniques: 15 evening lectures (weekly) beginning January 17. Technique of technical writing: 6 afternoon lectures beginning October 20, Fee: 10s.

Harwell Reactor School Standard course No. 23, part II (Harwell), part III (Winfrith), November 22–February 2. Radiation protection course No. 5, for graduates or persons of graduate standard: October 25–January 30, Fee: £250.

Lanchester College of Technology, Coventry Theoretical physics: evening course on Tuesdays, October 3–December 19, Fee: £1. High vacuum technology: part-time day course January 17–April 11. Recent advances in materials science: November 9–10, lecturers from the College of Aeronautics, RAE, A. V. Roe, Austins and the Natural Rubber Producers R.A.

High Voltage Engineering Corporation . . .

"CHARGED PARTICLES"



Rensselaer Polytechnic Institute — one of the most powerful accelerator neutron sources ever built, this linac will yield up to 10^{14} fast neutrons/sec, or a thermal flux of 10^{12} neutrons/sec/cm², with peak energy at 77 Mev, and peak pulse current of 800 ma. Primarily for neutron-time-of-flight and nuclear reactor research, the accelerator will also aid RPI's solid-state and radiation effect studies.

High Energy Linacs

Today's rapid advances in particle accelerator technology are particularly illustrated by the microwave linear electron accelerator (linac). Spurred by experimental requirements for more intense bursts of high-energy electrons and neutrons contained within precise limits of time and space, High Voltage Engineering and Applied Radiation Corporation have sustained intensive development of linacs. The result has been consistent improvement in linac reliability, and a series of record-breaking machines for research.

Two research linacs of considerable sophistication are now being installed at Yale University and Rensselaer Polytechnic Institute physics departments. The Yale machine is a five-section L-band accelerator, producing 28 kw of average radiation power and peak energies of 77 Mev. It will be used in a broad physical research program with emphasis on nuclear cross-section investigations. RPI's accelerator is an unusually powerful neutron physics research tool.

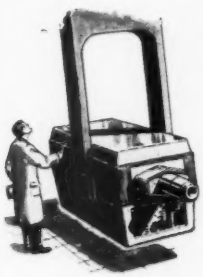
The accelerators of the near-future are exemplified by the machine now being built for the U.S. National Bureau of Standards. This linac, designed to performance specified by the NBS, will produce electron beam peak energies up to 150 Mev. Its 40 kw power output at 100 Mev will be greater than any previously obtained from a linear accelerator and about 100,000 times that obtainable from existing NBS high energy accelerators.

Availability of the intense high energy electron beam — and of secondary radiations such as x-rays, positrons and neutrons — opens up new research areas for NBS scientists. The linac will be used in low temperature chemistry, solid state physics, metallurgical studies, neutron activation analysis, nuclear alignment studies and determination of radiation standards.

Machines of such power were not available previously, and provide the experimenter with many intriguing opportunities.

Applied Radiation

As a powerful source of ionizing radiation, the linac is also a prime candidate for industrial radiation programs where electron penetration above 3 Mev is required. For example, most of the surgical sutures used today (made by Ethicon, Inc., a division of Johnson & Johnson) are electron-beam sterilized in aluminum-foil packages by industrial linacs operating on a two-shift production basis.



Development at High Voltage Engineering and ARCO has led to compact microwave electron accelerators for x-ray inspection and deep-x-ray therapy. High energy x-ray linacs can radiograph through two feet of steel or non-destructively inspect our biggest solid fuel rocket engines. Medical x-ray linacs provide the radiologist with a new precision therapy tool for treating deep-seated malignancies.

If you see the possibilities for accelerators in your research program or have a challenging radiation application, we'd be pleased to receive your inquiry.

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ISOTOPE REVIEW

NEW TECHNIQUES

Alpha irradiation of copper

Irradiation of a copper target with alpha particles produces a smooth finish, contrary to expectations, it is reported from the Laboratory for Physics, Munich College of Technology. The annual assembly of the Isotopen-Studiengesellschaft in Frankfurt was told by Professor Riehl of Munich that it had been intended to study irradiated surfaces under the electron microscope to get more data on the formation of thermal spikes in irradiated material by fission fragment recoil and other fission effects. It was found that the electron microscope did not show up spike areas; moreover, alpha bombardment caused a marked smoothing effect on the metal surface by forming large numbers of atoms out of the normal lattice into interstital positions.

The laboratory also attempted to produce ' cold sintering ' by using high energy irradiation of compacted powders. It was found that the method was possible in principle but that the neutron dose to attain satisfactory effects would have to be very high.

Chemical process control

A new technique, now under study at the Battelle Memorial Institute, Ohio, promises to provide an answer to some of the problems of chemical process control. The method studied involves the addition of intrinsic radiotracers to a solution or slurry. For instance, when removing cadmium from zinc sulphate electrolyte, radioactive cadmium is added to the electrolyte. The level of radioactivity is measured at the start and end of the continuing process. Comparison of the two readings shows what proportion of the cadmium has been removed, says an article in the Battelle Technical Review for June. Spot checks by conventional chemical analysis have proved the correctness of the readings. Other experiments have been carried out on the removal of iron from mixed nickel cobalt sulphate solutions and manganese from process water.

Iodine - 125 production plan

A method of producing iodine-125 in quantities potentially large enough for use in hospitals throughout the world in thyroid and liver tests has been developed by a University of Chicago scientist. Hospitals have been using a related isotope, iodine-131, as a tracer in thyroid and liver tests. Chief advantage of the new isotope is that it emits ' soft X-rays ' with only 10% of the radiation dose rate of iodine-131.

Xenon-124 is the raw material for the production of iodine-125. According to the developer, Dr Paul V. Harper, professor of surgery at Chicago, the USAEC is to manufacture the new isotope at its Oak Ridge, Tennessee, plant. The method of production is to bombard xenon-124 with neutrons to increase its atomic weight. This is carried out with the gas under pressure of 100–200 atmospheres to increase the yield of the final product. The atomic weight rises to 125 from 124. Then the cylinder of xenon-125 gas is stored for its 18-hour half-life until it decays to become iodine-125. Advantages claimed for iodine-125 over iodine-131 are: a usefully long half-life (60 days against 8 days); a reduction of radiation exposure to the patient by a factor of 10 to 20; the use of greatly reduced scintillation crystal size and shielding; marked improvement in the contrast on scintillation scans; and counting with great (60–70%) efficiency in conventional well counters.

Tritium tagging for lake

Lake McMillan, near Carlsbad, New Mexico, is to be tagged with tritiated water in an attempt to determine the extent of its underground reservoir. A solution of tritium will be released into the lake by gravity feed from a moving boat so that the tracer will be evenly distributed. After the tagging, samples will be taken to determine the volume and rate of movement of the water in the reservoir. The underground reservoir has been estimated to be a vast lake more than five miles in diameter.

NEWS ROUND-UP

Irradiation service centres

Irradiation service centres will be established in Paris and Tokyo by the end of this year for scientific research and commercial processing. This was announced by Dr K. H. Morganstern, President of Radiation Dynamics Inc., Westbury, New York. His firm is manufacturing the basic equipment for these centres, the Dynamitron multi-million volt particle accelerator. C. Itoh Corporation has purchased a Dynamitron for the Tokyo centre and the Paris centre is to be a joint operation of Leon Adany Research Laboratories of France, Radiation Dynamics Inc. and Westrex Corporation. The latter concern is responsible for European sales distribution of the Dynamitron. The machine is currently being used for sterilization of sutures and other pharmaceutical packaged products. Additional service centres in other parts of the world will be set up, says Dr Morganstern.

UK firm buys accelerator

Smith & Nephew Associated Companies Ltd in the UK, have purchased a Van de Graaff accelerator from the USA. The cost is £100,000 and the apparatus has been specially built for the Group's requirements. It will be in operation in 12 months time and will be used to determine the optimum conditions of sterilization for the Group's pharmaceutical products. This could result in a wider range of pre-sterilized products being made available.

ORNL's largest Sr-90 shipment

A 40,000 curie source of strontium-90, to be used to power a US Navy weather station in the Antarctic has been shipped from Oak Ridge National Laboratory to the Martin Company where it will be inserted in a thermo-electric generator. The shipment was more than twice that made by ORNL in May (17,500 curies) for an automatic weather station in the Canadian Arctic (see *Isotope Review*, August and September). The latest shipment will be used to produce 250 watts of heat which will be converted to about 12 watts of electricity for powering the weather data telemetry unit.

Japanese radiotherapy unit Japan's first radiotherapy hospital unit has been formally opened at the National Institute for Radiological Science in Chiba Prefecture. Equipment will include a beatatron (35 MeV); caesium-137 fixed irradiation equipment and a cobalt-60 revolving type irradiation unit.

Ionizing radiations regulations The new safety regulations—The Ionising Radiations (Sealed Sources) Regulations, 1961—specify shielding and operational safety for gamma radiographic machines which, if provided in lead, would make the equipment unwieldy. A more efficient shielding is tungsten, which provides, in practice, about 50% better shielding than lead. Pantatron, of Hanover Square, London, have developed a typical gamma radiographic machine made wholly in tungsten. It is portable and still provides good shielding. The radiation source (iridium-192) can only be exposed by remote control.

Finnish isotope discovery Scientists at Helsinki University, Finland, are reported to have discovered a new radioisotope, Mercury-206. The half-life of the new isotope, said to be the result of alpha decomposition of lead-210, is put at 7·5 minutes.

Dosemeter standard The British Standards Institution has issued BS 3385 which lays down requirements for direct reading personal dosemeters for X- and gamma radiation.

Ionizing radiations at exhibitions An official code of practice to provide safeguards for the display at exhibitions of radioactive substances and machines producing ionizing radiations has been issued in the UK. Entitled ' Code of Practice for the Display of Sources of Ionizing Radiations at Exhibitions,' copies may be obtained from HM Stationery Office, price 6d.

USEFUL READING

The uses of neutron activation analysis in chemical process control, Lloyd Fite, James Anderson, Walter Breen, John Shanks and Richard Wainerdi, Texas A & M College. Paper presented at the American Institute of Chemical Engineers 1961 National Meeting.

Application of intrinsic radiotracers to the control of an iron precipitation process, J. F. Kircher, J. L. McFarling, P. Gluck and D. N. Sunderman, Battelle Memorial Institute, Columbus, Ohio.

Investigation of gasification processes of solid fuel by an isotope method, I. G. Petrenko (USSR), translated by J. J. Cornish. UK AERE translation, ref. TRANS 865, 18pp.

Radioisotope Applications Engineering, by Jerome Kohl, Rene D. Zentner, Herbert R. Lukens, Van Nostrand Nuclear Science Series, D. Van Nostrand Company Inc., Princeton, New Jersey, 551 pp, £6 4s.

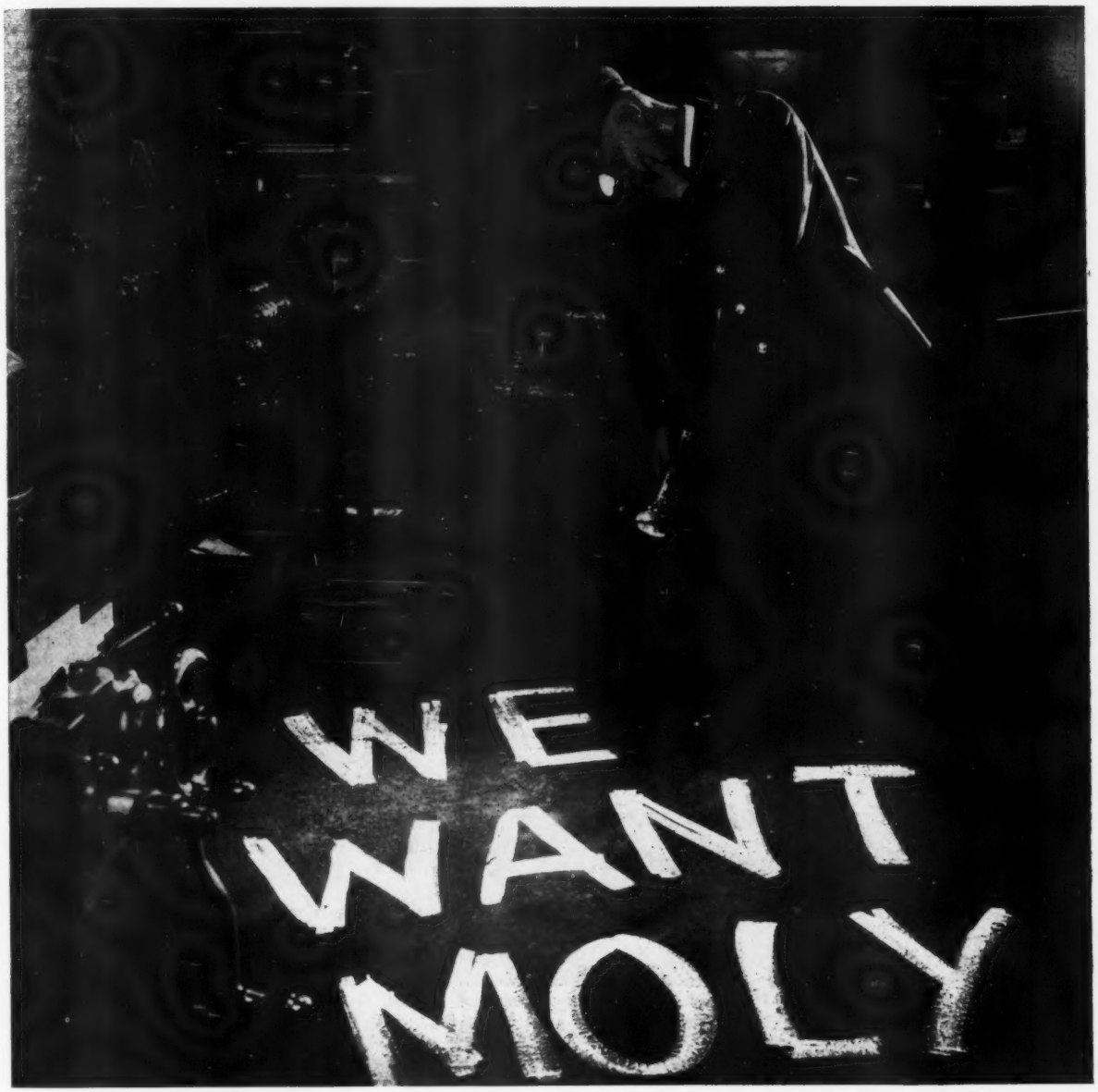
Cancer Research (TID-11132), describes the current USAEC cancer research programme. Available from Office of Technical Services, US Department of Commerce, Washington 25. $2.25 a copy.

Radiochemistry, translations from the Soviet journal Radiokhimiia. Published twice yearly by Pergammon Press. Annual subscription £15.

The work of the Isotope Research Division, J. L. Putman, head of the Isotope Branch, Isotope Research Division, Wantage, UKAEA. Issued by UKAEA Public Relations Branch and is the text of an article in the April-May, 1961, issue of State Service.

Watson Industrial X-ray News, Vol. 1, 1961. A periodical review of developments in X-ray, radioisotope and allied equipment. Published by Watson (Electro-Medical) Limited, Industrial Division, East Lane, North Wembley, Middlesex.

The Ionising Radiations (Sealed Sources) Regulations, 1961. S.I. No. 1470, HM Stationery Office, price 9d net.



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CAPT. PATTISON
joins
Plessey Nucleonics

People

by John Radford

W. P. RAFFAN
heads
detector unit

ONE OF America's leading nuclear physicists has become the fourth Director-General of the 12-nation European Organization for Nuclear Research (CERN). He is **Professor Victor F. Weisskopf** who joined CERN in September 1960 as a member of the Directorate responsible for research. Professor Weisskopf succeeds **Dr J. B. Adams** who returned to the UK as Director of the Controlled Thermonuclear Research Establishment at Culham. Born in Vienna 53 years ago, Professor Weisskopf became a naturalized US citizen in 1943. He is a corresponding member of the French Academy of Science, a member of the US National Academy of Science and until the end of 1960 was president of the American Society of Physics.

The former Assistant Director of Electrical Engineering with the Director-General, Ships, Admiralty, Bath, **Captain G. R. B. Pattison** (Ret'd) has been appointed deputy general manager by Plessey Nucleonics Ltd, one of the Plessey Group of companies.

Head of its newly-formed Solid State Division is to be **W. P. Raffan,** says an announcement by 20th Century Electronics Ltd. Formerly with Rank Cintel Ltd, Mr Raffan has, during the past three years, been engaged in the development of special solid state devices. The new division he heads is engaged in the development of a full range of nuclear radiation detectors.

Nuclear Developments Ltd, the private company formed recently by Imperial Chemical Industries Ltd (Metals Division), Rolls-Royce Ltd and The Rio Tinto Co. Ltd, has appointed the following board of directors: chairman, **J. N. V. Duncan** (managing director, Rio Tinto); **R. W. Wright** (deputy managing director, Rio Tinto); **Sir Mark Turner** (director, Rio Tinto); **J. D. Pearson** (chief executive and deputy chairman, Rolls-Royce); **A. A. Rubbra** (director, Rolls-Royce); **L. Barman** (special executive, Rolls-Royce); **Dr J. Taylor** (director, ICI); **St J. de H. Elstub** (chairman, ICI Metals Division); **Dr R. L. P. Berry** (director, ICI Metals Division). The executive director and general manager is **S. S. Smith** (research manager, ICI Metals Division) who has been closely associated with nuclear engineering since 1941. Company secretary is **P. J. G. Elwes,** Rio Tinto.

H. A. Digby-Bell is now manager, general products, AMF Ltd, Savile Row, London, and also responsible for nuclear liaison for AMF (Atomics) with Mitchell Engineering Ltd and Pye Ltd.

J. V. Daniel, managing director of Crompton Parkinson, has resigned from the board of Atomic Power Constructions. This follows the company's recent withdrawal from the APC Consortium.

Cyril G. Conway, in his new post as sales manager of Great Lakes Carbon International Ltd, will have as his main responsibility the administering and extending in the UK and Europe, sales of graphite and carbon products made by Great Lakes in the UK and USA.

BUSINESS NEWS

NIRNS ORDERS ATLAS COMPUTER A Ferranti Atlas electronic digital computer has been ordered for the National Institute for Research in Nuclear Science. Its cost, together with the necessary buildings, will be about £3·5 million. The computer will be installed at the Institute's Rutherford High Energy Laboratory, Harwell, for common use by the universities, the UKAEA, government departments and the NIRNS itself. It should be ready early in 1964. The Atlas computer has been developed by Ferranti in co-operation with scientists at the University of Manchester where the prototype is now being assembled.

POWELL DUFFRYN REPORT Powell Duffryn Carbon Products is still heavily engaged in the machining of graphite for the Hunterston nuclear power station, says the annual report issued by Powell Duffryn Ltd. The report says the 'crucial question is whether there is going to be any continuity of work for our machine shops. Particularly since the cut-back in the nuclear energy programme, there is in this country and excess of contracting capacity, including an excess of graphite machining capacity and it is difficult to see how that capacity can remain fully employed.' The report adds that every effort is being made to develop the previously existing activities of this company, particularly the manufacture of heat exchangers and other equipment for the chemical industry.

CIMEX PLANS EXPANSION Cimex Ltd have formed a nuclear department to look after all overseas sales of both standard and special ventilating nuclear equipment. The new branch is to be operated by Nuclear Research Applications Ltd, a company with world-wide associations among users of isotopes and auxiliaries for nuclear power and medical projects. This remarkable development follows the entry by Cimex just over a year ago into the nuclear cleaning field. The firm developed an experimental absolute nuclear filter machine which was so successful that orders have been received both at home and abroad.

• **C. A. Parsons & Co. Ltd.** have signed a licence agreement with **Zallea Brothers,** Delaware, USA, for the manufacture and sale of thinwall-bellows expansion joints of Zallea design.

• The **Production Engineering Research Association** is compiling a World Register of production engineering research carried out in the years 1959-62. It will also summarize plans for research for the following three years. Organizations carrying out any form of production engineering research are invited to write to PERA, Melton Mowbray, Leics, for a copy of their questionnaire.

• Four radiation shielding windows, each equivalent in protective properties to nearly six feet of concrete, have been ordered by the UKAEA, Windscale, from the **Chance-Pilkington Optical Works,** North Wales. They are to be used in a series of cave facilities at Windscale for the viewing and remote control handling of irradiated fuel elements.

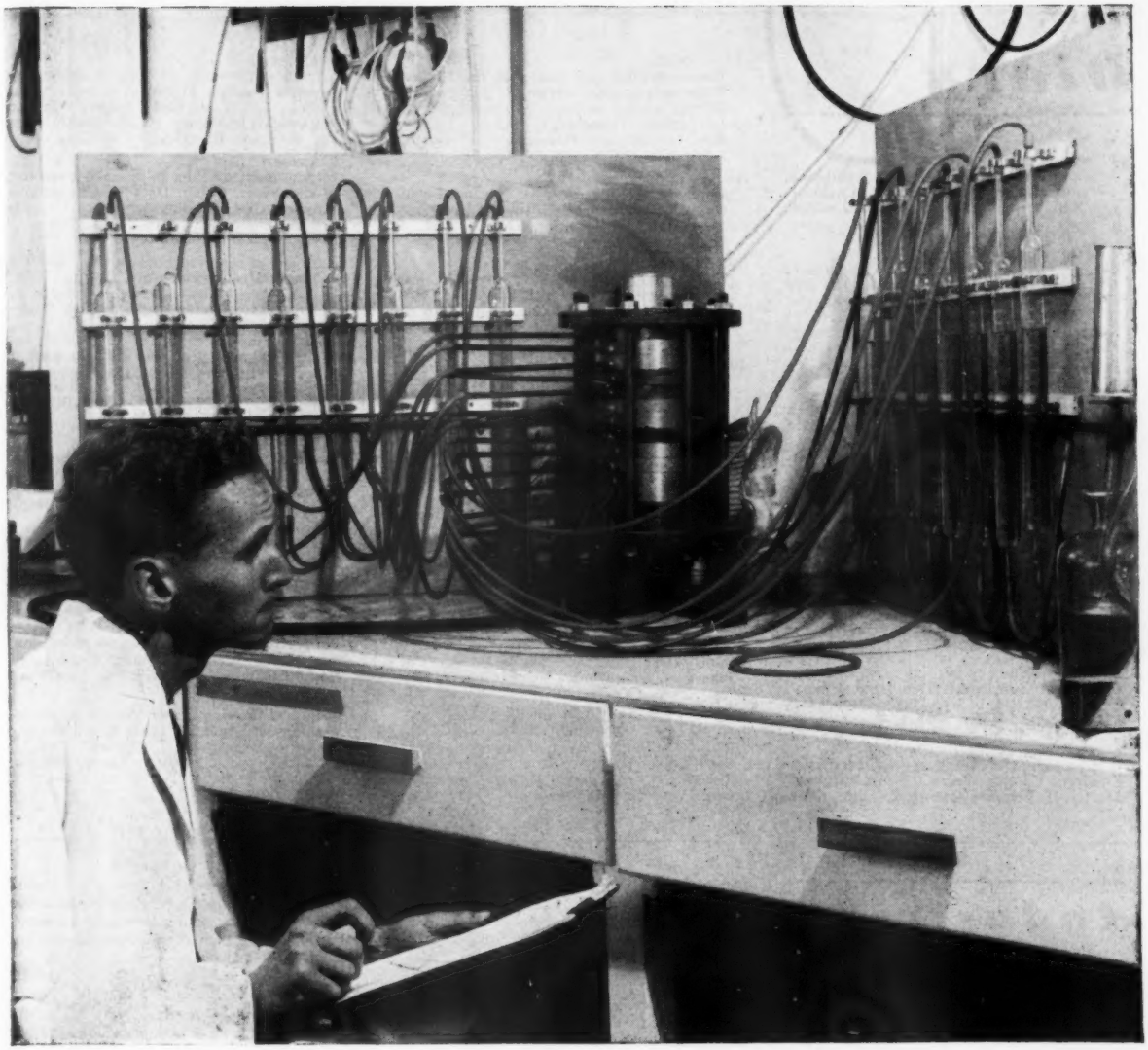
• **Uddeholm Ltd,** the British associates of **Uddeholms A.B. Sweden,** have set up a new division. Known as the Chemical and Nuclear Plant Division, its concern will be design, fabrication and sales in stainless and clad steel of all types of tanks, pressure vessels, heat exchangers, etc.

• **Servomex Controls Ltd** has sold an assortment of 39 voltage stabilizers, ac and dc, to the Institute of Physics, Helsinki University. The £5000 order was negotiated direct with Professor Nurmia who is re-equipping the Institute.

• **Ultra Electronics Ltd** has reached provisional agreement with **K. G. (Holdings) Ltd** to acquire, for £125,000 approximately, the entire share capital of its subsidiary, **W. S. Electronics Ltd.**

• **Tracerlab Inc.** has been selected as the major supplier of nuclear equipment to be used by the Office of Atomic Energy of Korea.

• **High Voltage Engineering Corporation** has announced the sale of a 5·5 million electron volt nuclear physics research accelerator to the Southern Universities Nuclear Institute in the République of South Africa.



One of the many test rigs used in the seal development and proving programme initiated by FR, some aspects of which are now being sponsored and extended by the Central Electricity Generating Board.

FR a unique and expanding service

for the Nuclear Industry

Since 1956, when they were called upon to design a standpipe coupling for Berkeley power station in co-operation with Associated Electrical Industries-John Thompson (now The Nuclear Power Group) design engineers, Flight Refuelling Ltd. have been making an ever-increasing contribution to the nuclear industry. Their long experience in dealing with liquids and gases under extreme conditions of temperature, pressure and corrosion, and their unrivalled test and manufacturing facilities, have equipped them to handle the development, proving and production of many devices for nuclear use.

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Diary

3–12 OCTOBER
Second **Electronic Computer Exhibition,** Olympia. Enquiries, Electronic Engineering Association, 17 Fleet Street, London, EC4

4–6 OCTOBER
Clean Air Exhibition and Conference, Brighton. Organized by National Society for Clean Air, Field House, Breams Buildings, London, EC4
Symposium on **electronic data processing,** London. Organized by the British Computer Society Ltd

5–6 OCTOBER
Export conference, London. Details, British Electrical & Allied Manufacturers Association, 36 Kingsway, London WC2
Symposium on **cleaning, preservation and packing of nuclear materials and equipment,** Caxton Hall, London. Organized by Institution of Nuclear Engineers

10 OCTOBER
The trends and progress of nuclear power station design, W. G. Busbridge, UKAEA, Wantage. Manchester branch meeting, Institution of Plant Engineers. Venue, Manchester Literary & Philosophical Society, 7.15 pm

10–21 OCTOBER
Industrial Efficiency & Safety Exhibition City Hall, Manchester. Details, Provincial Exhibitions Ltd, City Hall, Deansgate, Manchester 3

16–18 OCTOBER
Conference, **The metallurgy of beryllium,** London. Details, Secretary, Institute of Metals, 17 Belgrave Square, London, SW1

17 OCTOBER
Instrumentation and control at the Hinkley Point nuclear power station, R. B. Quarmby. Bristol section meeting of the Society of Instrument Technology. Venue, Department of Physics, University of Bristol, 7.30 pm

17–19 OCTOBER
Engineering Industries Association **Engineering Display,** Royal Horticultural Society New Hall, Westminster. Details, EIA, 9 Seymour Street, London, W1

19 OCTOBER
The maintenance problems in a nuclear power station, J. R. Treharne, UKAEA. Blackburn branch meeting, Institution of Plant Engineers. Venue, Castle Hotel, Blackburn, 7.30 pm

19–20 OCTOBER
Scale-up and pilot plants, Royal Overseas League, St James's, London, SW1. Organized by Institution of Chemical Engineers

31 OCTOBER–3 NOVEMBER
Effluent and water treatment exhibition, Seymour Hall, London. Details, Thunderbird Enterprises Ltd, 140 Cromwell Road, London, SW7

OVERSEAS

18–30 SEPTEMBER
Forum on research vessels, Tokyo, Japan. Sponsored by UN Food and Agriculture Organization

1–8 OCTOBER
Thirty-third international congress of **industrial chemistry,** Bordeaux. Details, Société de Chimie Industrielle, 28 rue Saint-Dominique, Paris 7e, France

2–6 OCTOBER
Third international conference on **powder metallurgy,** Madrid. Details, Directeur, Délégation Espagnole, Institut International de Soudage, Serrano 144, Madrid

3–5 OCTOBER
Second symposium on **physics and nondestructive testing,** Argonne, Illinois, USA. Details, Dr W. J. McGonnagle, Argonne National Laboratory, 9700 South Cass Av., Argonne, Ill, USA

7–9 OCTOBER
International meeting on **surface treatment of aluminium,** Milan. Details, Associazione Italiana di Metallurgia, Centro Leghe Leggeri, Via Moscova 16, Milan, Italy

10–12 OCTOBER
Thirtieth symposium on **shock, vibration and associated environments,** Detroit, USA. Organized by Office of the Directors of Defense Research and Engineering, Washington, USA
Nuclear reactor chemistry and fifth conference on **analytical chemistry in nuclear power,** Gatlinburg, Tennessee. Organized by Oak Ridge National Laboratory. Details, C. D. Susano, ORNL, PO Box X, Oak Ridge, Tenn, USA

10–12 OCTOBER
Fourth Japan conference on **radioisotopes,** Kyoto, Japan. Organized by Japan Atomic Industrial Forum, No 1, 1-chome, Shiba Tamura-cho, Minato-ku, Tokyo, Japan

16–20 OCTOBER
IAEA symposium on **utilization and programming of research reactors,** Vienna

23–26 OCTOBER
Eighth annual meeting, Professional Group on Nuclear Science of the Institute of Radio Engineers and USAEC. Includes symposium on **aerospace nuclear propulsion,** Las Vegas, Nevada. Details, Institute of Radio Engineers, 1 East 79th St, New York

23–30 OCTOBER
Technical meeting on the **control of wholesomeness of irradiated foods** as a basis for legislation, Brussels, Belgium. Details, R. A. Silow, chief, Atomic Energy Branch, FAO, Viale delle Terme di Caracalla, Rome, Italy

Industrial Literature

Ultra-pure elements. Light's latest catalogue lists over 250 materials for solid-state physicists covering ultra-pure elements, single crystals and compounds.
★ 248

Radiation therapy controls. A recent issue of the Metal Industries ' Review ' contains an article on the control system used in the cobalt therapy unit at St Thomas's Hospital. It has three co-ordinated servomechanisms.
★ 249

Gauges and tools. The 8th edition of the Handbook of the Gauge and Tool Makers' Association is now available. Details are given of the 386 member companies and a buyers' guide index is included.
★ 250

Electric heating. Morganite Electroheat have put out a new publication on ' Crusilite '. Technical specifications of each type of heating element are included.
★ 251

Induction heating. ' Westinghouse Engineer ' for May contains an article on the induction heating of metal, giving theory and application.
★ 252

Flexible joints. A new brochure from Avica describes their work in the field of gimbal type flexible joints and bellows assemblies, catering for many different layouts in pipe and duct-work systems.
★ 253

Ultrasonic cleaning. The advantages of ultrasonic cleaning are given in recent pamphlets from Kerry's. One has details of a general purpose range of manually operated cabinets operating at 40 kc/s; another covers the type USC·1 and ·3 cabinets for use with aqueous cleaning solutions.
★ 254

Civil engineering. Basic research in rock mechanics is becoming increasingly important in foundation engineering. Work being done in this field by the new company, Rock Mechanics, is described in a new geotechnical pamphlet.
★ 255

Chemical processing. A recent Clark Bros publication describes the Podbielniak line of centrifugal contactors, solvent extractors, chemical reactors, separators and clarifiers, and gives operating principles and applications.
★ 256

Measuring form errors. Recently issued by Elliott-Automation is a brochure describing the ' Rondell ' form error-measuring instrument which measures not only the roundness errors of an object but also errors in concentricity, perpendicularity, etc. to within 3 micro-inches.
★ 257

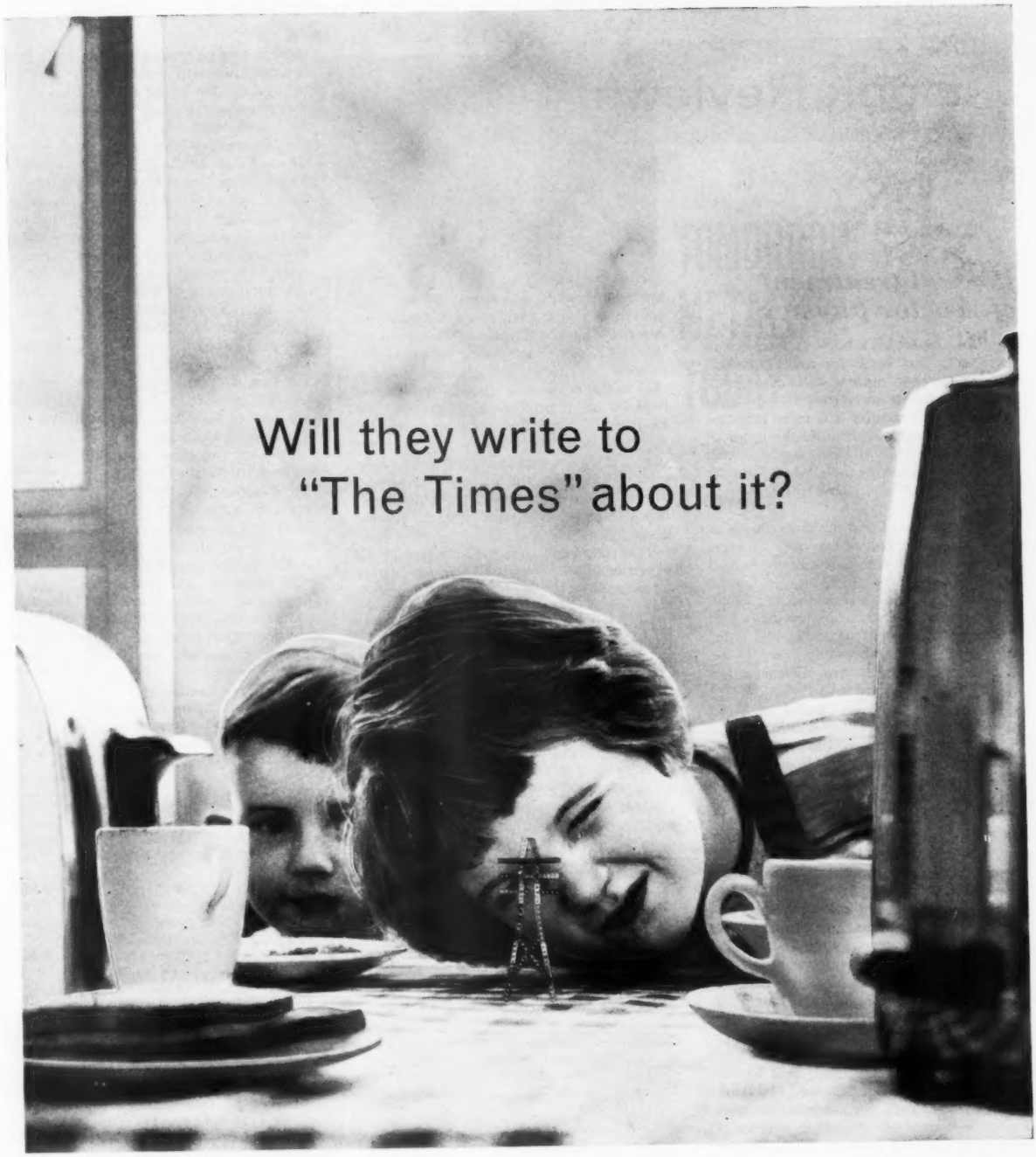
Electronic equipment. Solartron's annual review for 1960 surveys progress made in the development of computers, measuring instruments, and data handling and process control systems.
★ 258

Remote handling. General Mills' remotely controlled vehicle ' Little Ranger ' for handling operations in hazardous environments is capable of surmounting minor terrain irregularities or obstacles. A data sheet is now available.
★ 259

Nucleonic instruments. Recent specification leaflets from Isotope Developments cover a tritium scintillation Counter 6012 for measuring milli-microcurie quantities of low-energy-beta emitting isotopes, a timer 1860 which can be automatically switched off at preset times between 10 and 100,000s, a ratemeter 1815 with an input amplifier accepting $\frac{1}{4}$V-50V pulses, and scaler 1805 with a total count capacity of 99,999 pulses and a resolution time of 275 μs.
★ 260

Gas cleaning. Both Sturtevant and W. C. Holmes have issued publications describing their design of electrical precipitators. The former company build two types of plant, the tubular and the plate. The latter use, in certain cases, barbed wire for the negative electrode and several types of positive plate electrodes.
★ 261

★ *For further information on any item, circle the appropriate number on the reply card facing page* 108.



By the time these children are ten years older, Britain's power demands will have doubled. But the number of transmission towers will *not* have doubled. On the contrary — because the Central Electricity Generating Board is adopting 400,000 volt transmission, fewer new towers will be needed. The new power system will use some existing towers, suitably reinforced, and a limited number of new, slightly taller ones. By Act of Parliament, the C.E.G.B. must provide an efficient, economical electricity supply, while preserving visual amenity as far as possible.

■ **These advertisements are appearing in the farming and country magazines. The Central Electricity Generating Board thank electrical contractors for their co-operation in the past, and know that they will do all they can to preserve the amenities of the countryside.**

CEGB

who make and supply electricity to 12 Area Electricity Boards in England and Wales (which re-sell to consumers) and British Railways.

Write for a copy of "Preserving Amenities" to The Central Electricity Generating Board, 83 Winsley Street, London, W.1

Book Reviews

Logical treatment of reactor physics

Professor Liverhant's book is intended to serve as a text book for undergraduates taking degrees in nuclear science or engineering. Although such students are non-existent in this country it is to be expected that such a book would fulfil the needs of newcomers to the nuclear reactor field, especially those taking the graduate courses run by many universities and by the Harwell Reactor School.

For a number of reasons this book is an improvement on the earlier ones covering the subject; much more attention is paid to the physics of the nucleus, i.e. to the microscopic processes involved in a chain reaction; and the treatment of the whole subject matter is up-to-date. In this latter respect valuable bibliographies cover the theories and practices now current within the industry.

The author has been careful to avoid slavishly following earlier books and he includes many features which have received scant treatment elsewhere. For example, in the section on reactor behaviour, the latest value is given for the delayed neutron fraction from U-235 but the author points out that the *effective* fraction varies from reactor to reactor and in a number of cases the old figure yields more realistic reactivity values.

One minor criticism can be made concerning layout. Some mention of the various types of reactors might well be necessary during the development of the theory of core physics, but the detailed descriptions and the reactor catalogue which are included at this point could well have been relegated to a later chapter or even to an appendix. Apart from this one lapse the subject is developed in a logical and extremely readable manner. The book is suitable not only for students but also for people engaged on other aspects of reactor work who wish to gain a better understanding of reactor physics.

A. C. Hughes

Elementary introduction to nuclear reactor physics by S. E. Liverhant. Wiley, London & New York, 1960. 447 pp. Price 78s.

Experimental nuclear fusion surveyed

There are now many volumes which report in detail the vast amount of research on controlled thermonuclear fusion in Soviet Russia, the USA, the UK and elsewhere. Many scientists must have felt the need for a reasonably comprehensive introductory volume. This book which fulfills the requirement, is a survey of the basic principles and of the experimental approaches being followed. After considering the physical conditions necessary for possible methods of achieving fusion, the authors discuss the properties of plasmas of thermonuclear interest, the methods of producing such plasmas, and the techniques for studying their properties. They then describe the work done on the pinch effect, the Stellarator, magnetic mirror systems, the Astron concept, and other proposed methods for plasma heating and confinement.

The treatment is directed primarily to experimentalists, but sufficient theory is introduced to enable the reader to understand the principles underlying the observed phenomena. Theoretical derivations are sometimes simplified to present a physical picture rather than a rigorous mathematical approach; however, theorists will find a useful guide to the many experimental results which require interpretation. In addition, numerous references provide a coverage of the now extensive literature of controlled thermonuclear reactions and allied topics. Perhaps the only small criticism of the book itself is the rather unattractive typographical presentation, coupled with too-extreme usage of a decimal numbering system and an awkward contents list and index.

There is no doubt that the volume provides a most useful and up-to-date introduction to this challenging new field of research. The practising engineer and scientist, as well as advanced students in physics and engineering, will find this a worthwhile investment.

B. C. Lindley

Controlled thermonuclear reactions by S. Glasstone and R. H. Lovberg. Van Nostrand, New York and London, 1960. 523 pp. Price 42s.

Practical approach to nuclear instruments

Based on practical work associated with a reactor course at the Birmingham College of Technology, a graded series of experiments have been assembled suitable for students of mixed disciplines in science and engineering. The introduction covers the design of experiments, apparatus and statistics of radioactivity, and forms a good basis for anyone starting a practical course in nuclear measurement techniques.

The question of radiation hazards is introduced early in the book and some simple experiments on monitoring and film-badge dosimetry are included. This topic is treated rationally and, while brief, contains sufficient detail for the levels of radiation liable to be encountered in the experiments described. Two points arise here, however: the value given for the maximum permissible weekly dose, 0·3 rad, is out of date by about 2 years, though the authors state that it is more usual to work to 0·1 rad/week, which is effectively the present value. Secondly, metal film badge holders only are described, whereas one of the most widely used types is made of nylon with metal filters incorporated in it.

A good range of experiments is given, covering Geiger, scintillation and neutron counting. The inclusion of work with gold-leaf electroscopes is worth while, since many of the problems of ionization chambers are thus emphasized; the construction of such an electroscope should form part of the training of anyone working with ionizing radiation.

There are two sections which might have been omitted; the first of these covers measurements of fundamental physical constants such as the velocity of light, Planck's Constant and e/m, while the second is on electronics. These are, primarily, for the non-physicist, but the time could probably have been better spent on other topics, such as the use of ionization chambers and proportional counters, and a more detailed comparison of the relative merits of Geiger and scintillation counters.

H. D. Evans

Practical nucleonics by F. J. Pearson and R. R. Osborne. Spon, London, 1960. 208 pp. Price 37s 6d

New books

• *Standard X-ray diffraction powder patterns* by H. E. Swanson *et al.* National Bureau of Standards Circular 539, vol. 10, 1960. US Gvt. Printing Office (per HMSO). 61 pp. Price 40 cents

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• *Power reactor technology* edited by J. K. Pickard *et al.* Van Nostrand, New York and London, 1961 417 pp Price 84s 6d

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• *Problems in quantum mechanics* by I. I. Gol'dman and V. D. Krivchenkov Translated from the Russian Pergamon, Oxford and London, 1961 275 pp Price 50s

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• *Extractive metallurgy of copper, nickel, and cobalt* edited by P. Quenau Based on an International Symposium held in New York, February 1960 Interscience, New York and London, 1961 647 pp Price £8

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• *Electronic tubes and semiconductor elements:* universal vade-mecum volume 1, compiled by P Mikolajczyk Pergamon, Oxford and London, 1961 1213 pp Price £7

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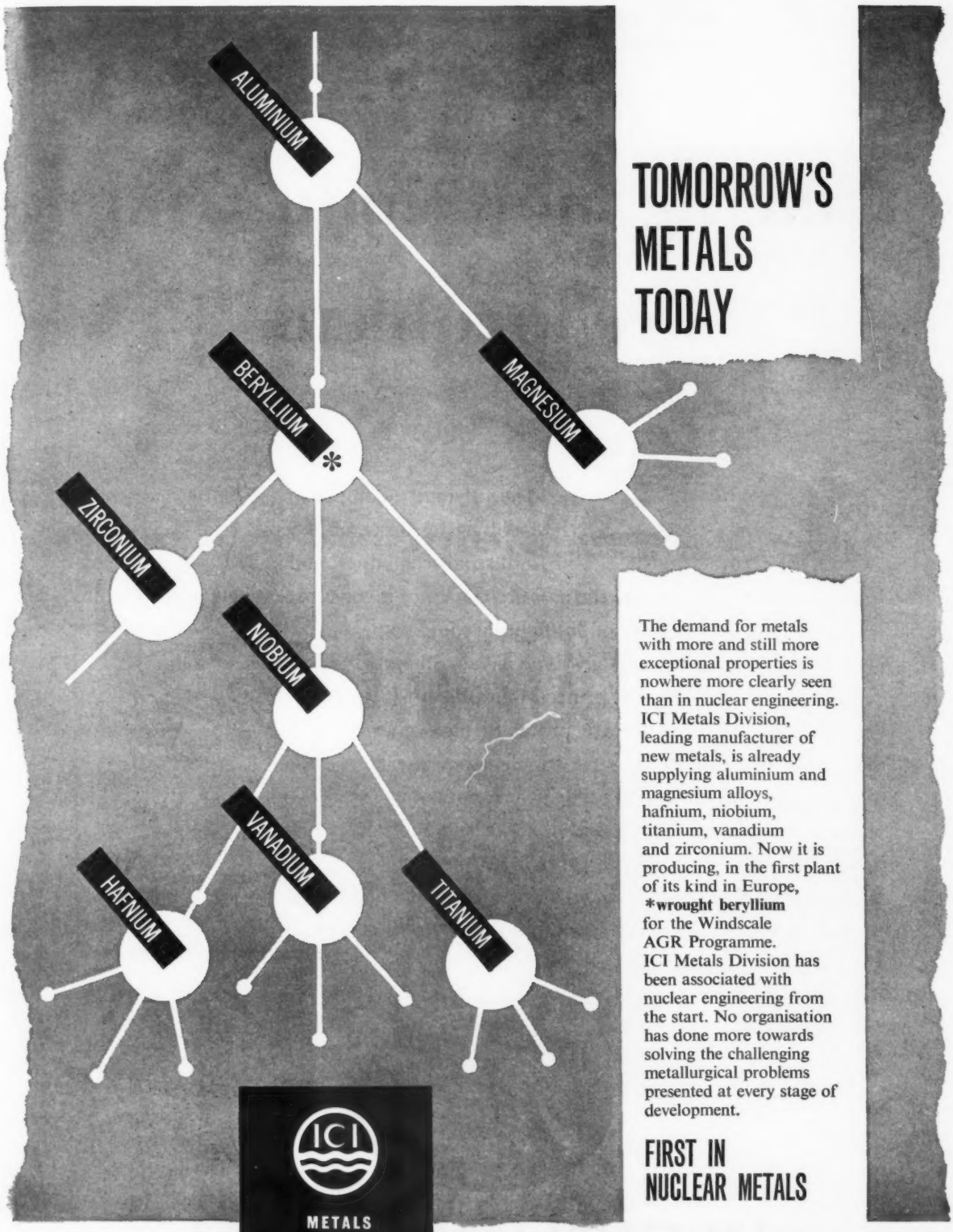

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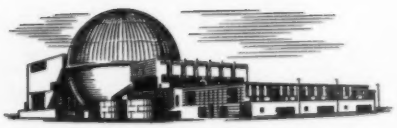

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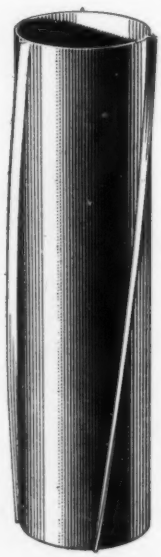

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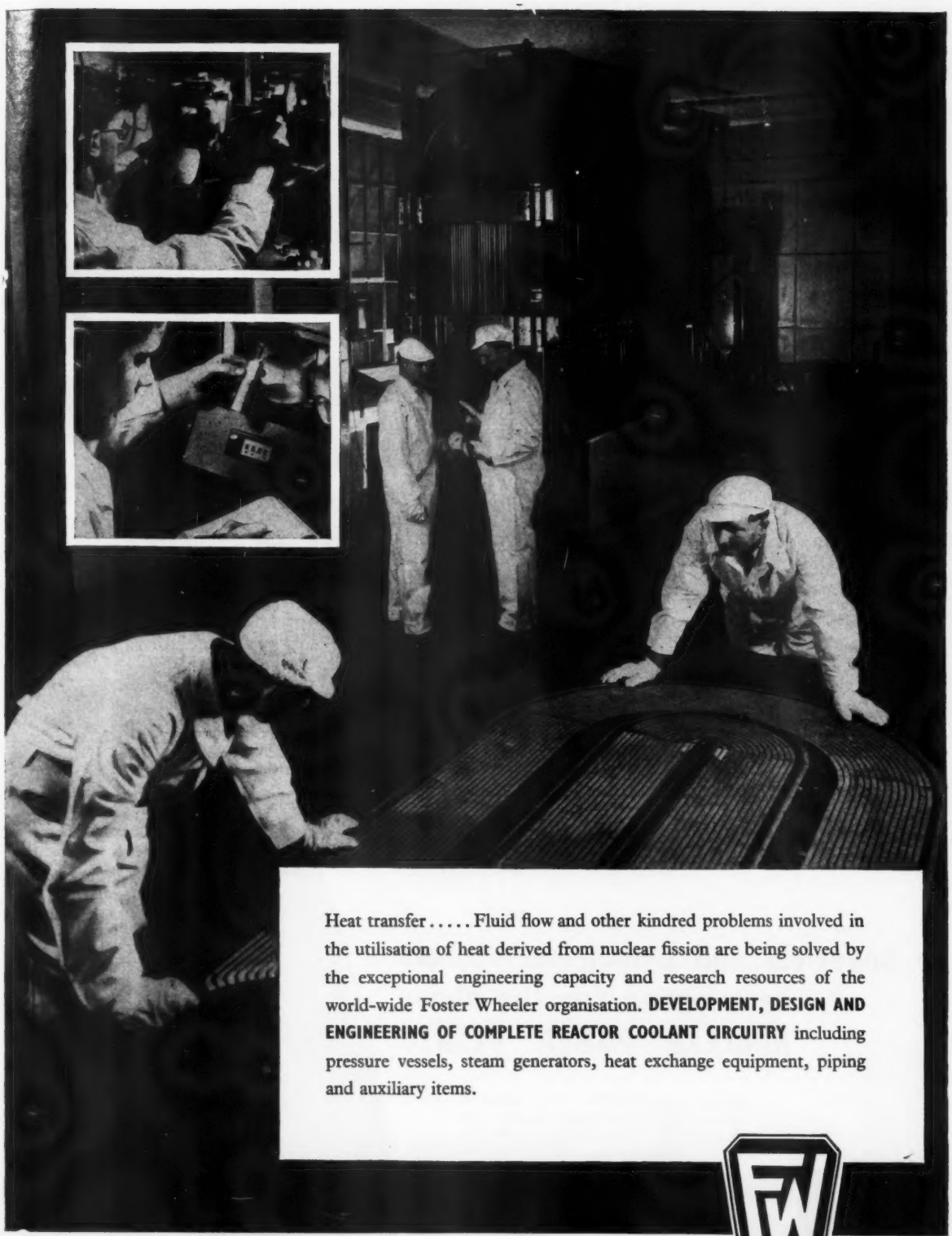

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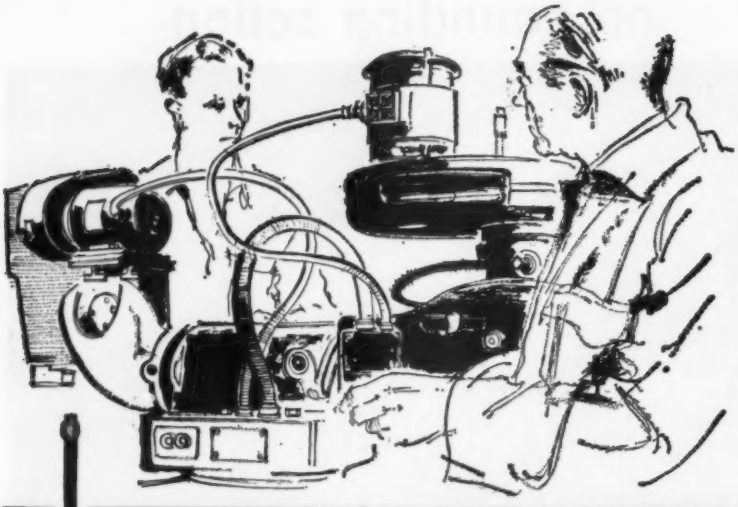

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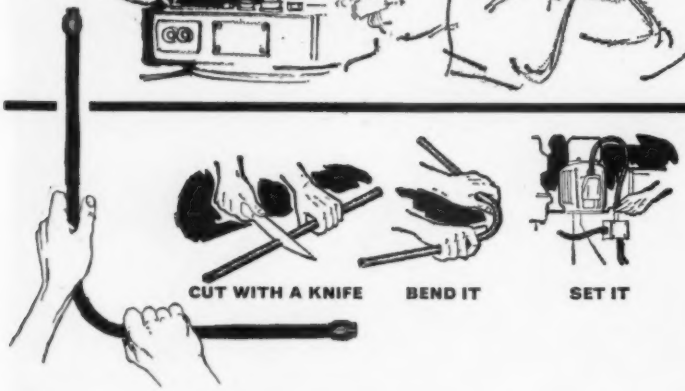

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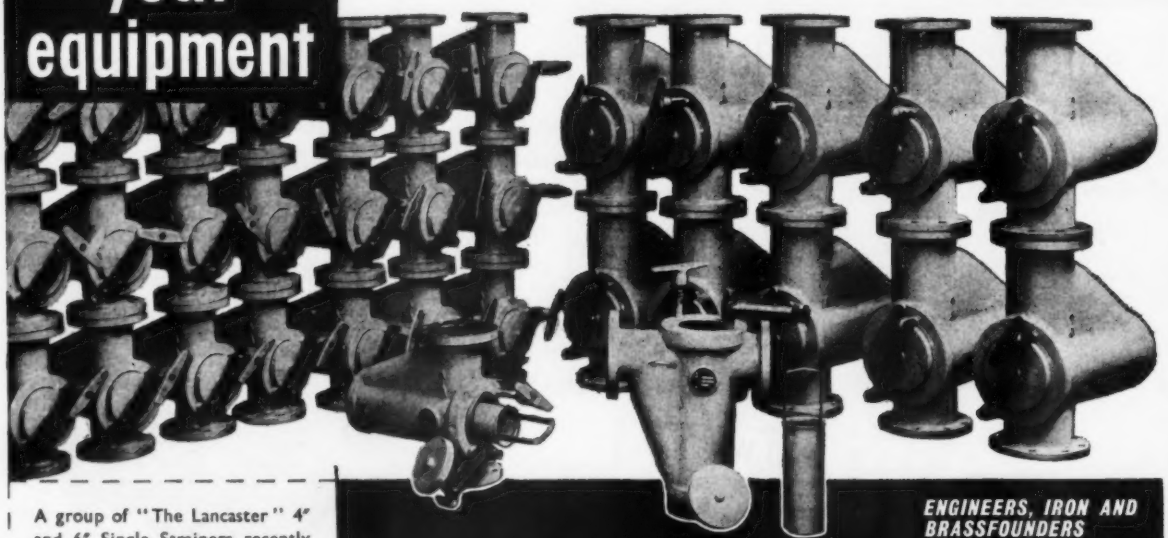

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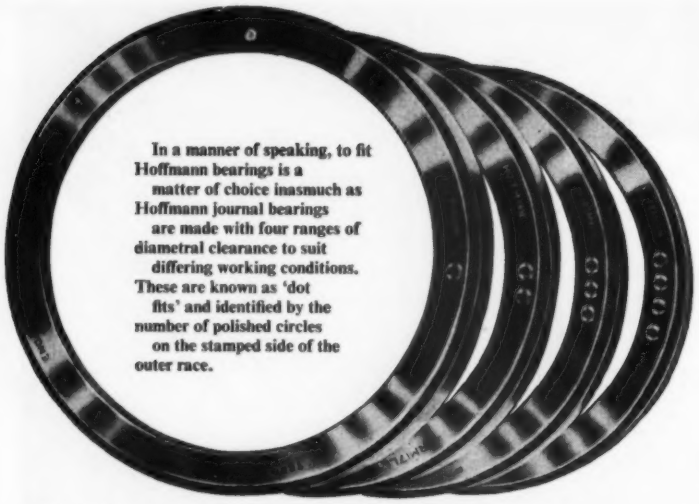

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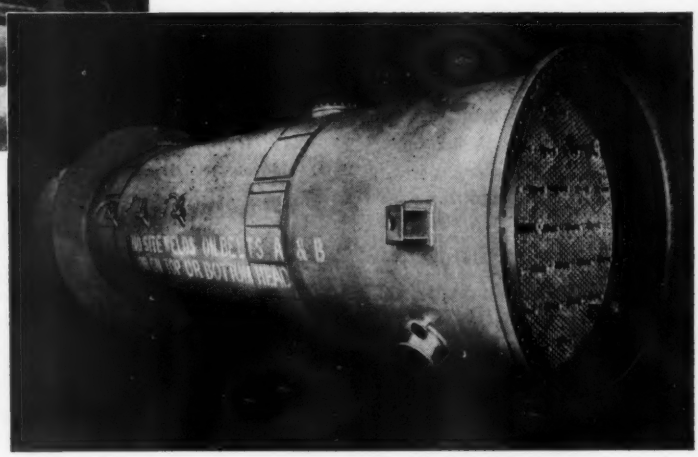

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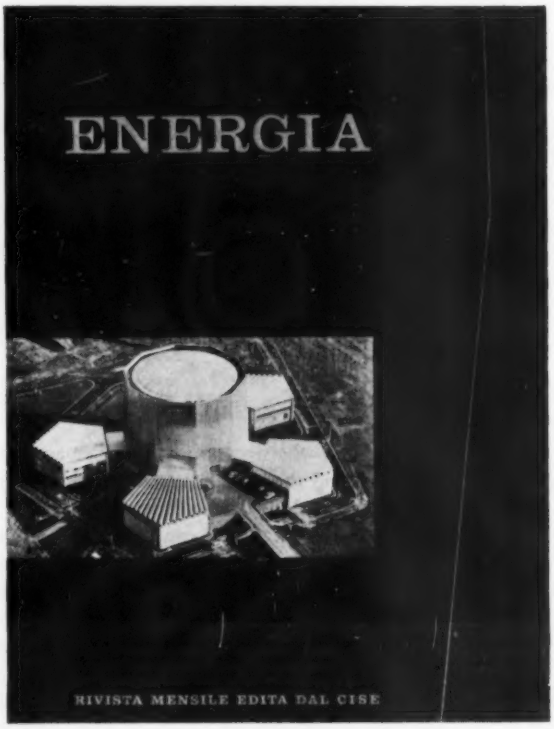

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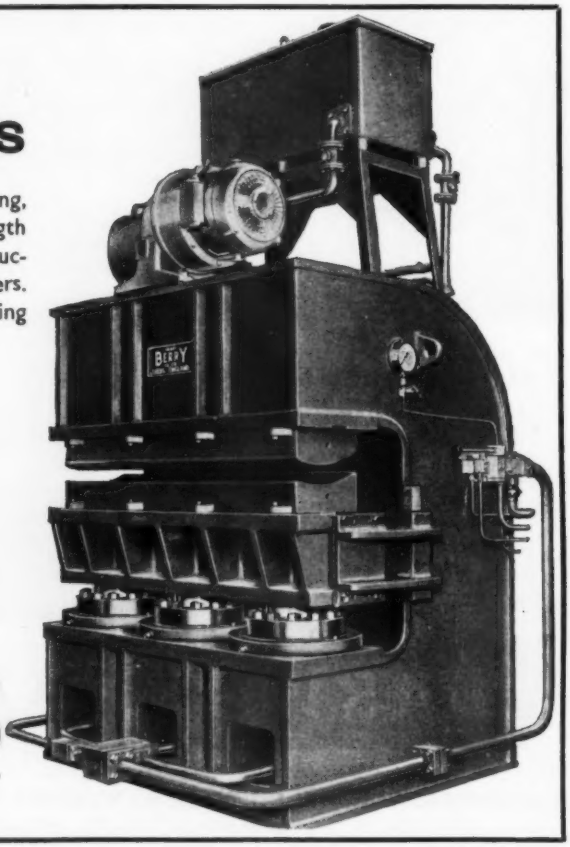

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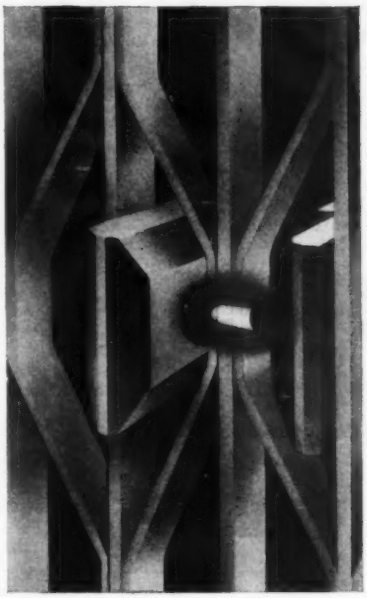

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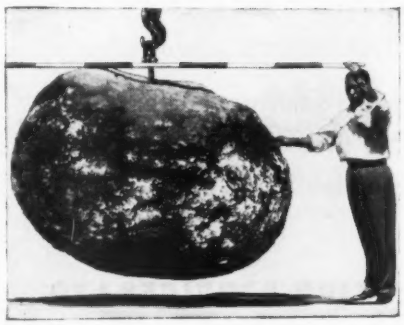

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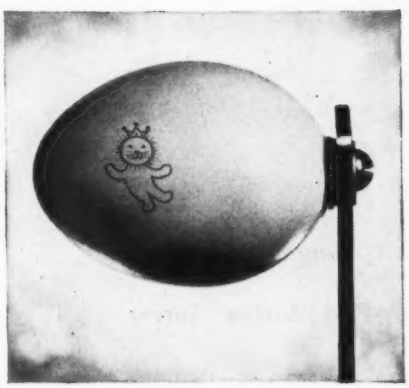

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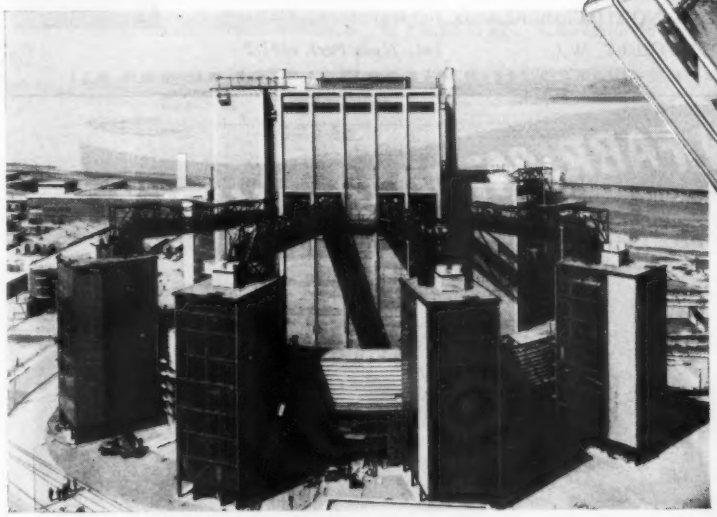

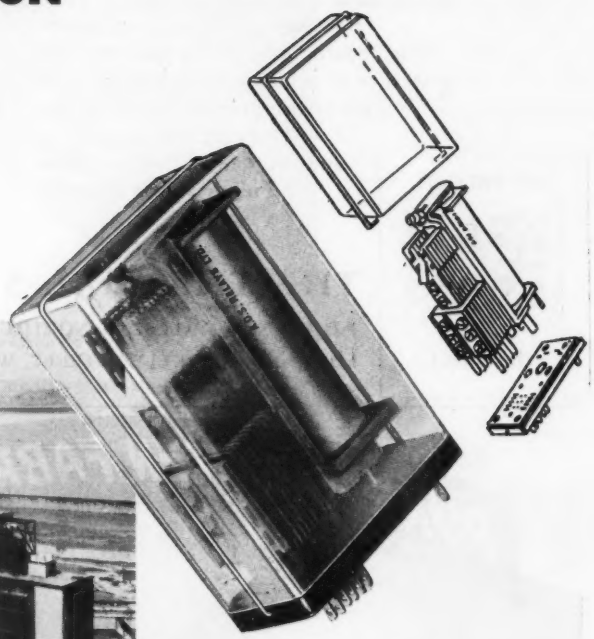

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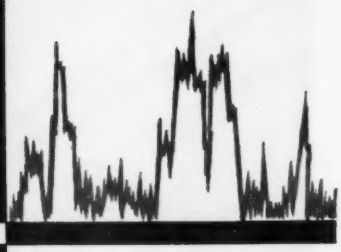

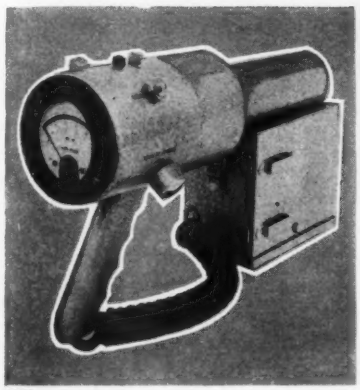

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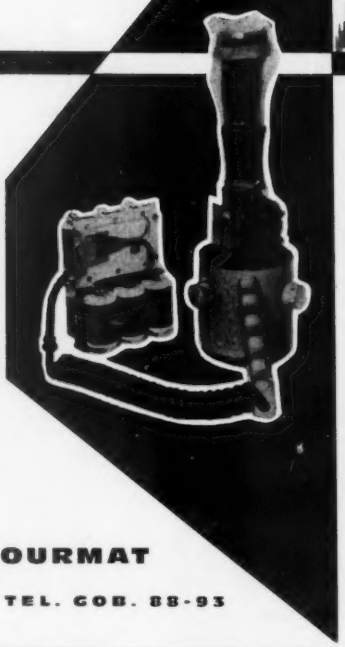

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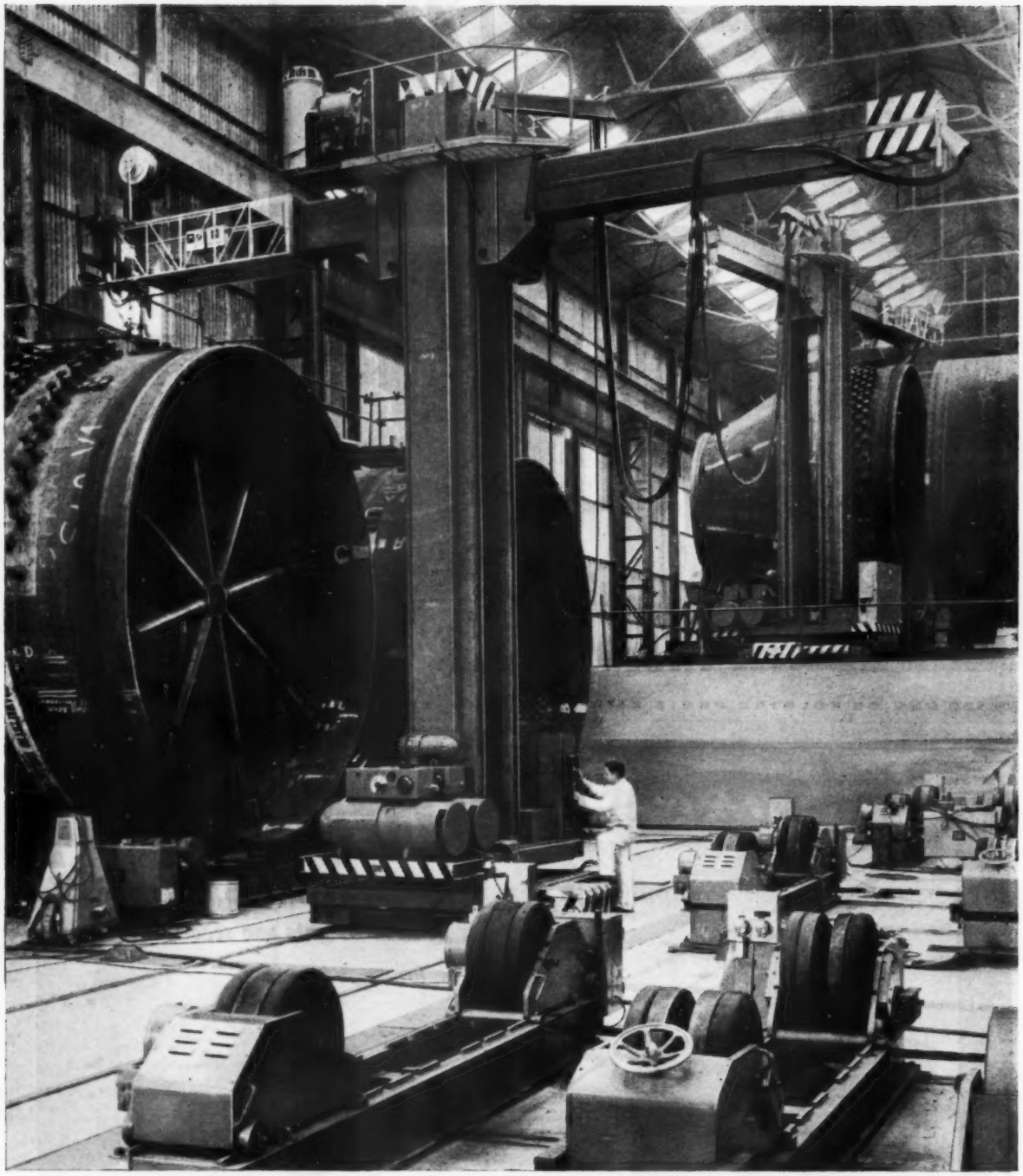

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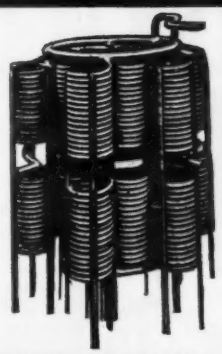

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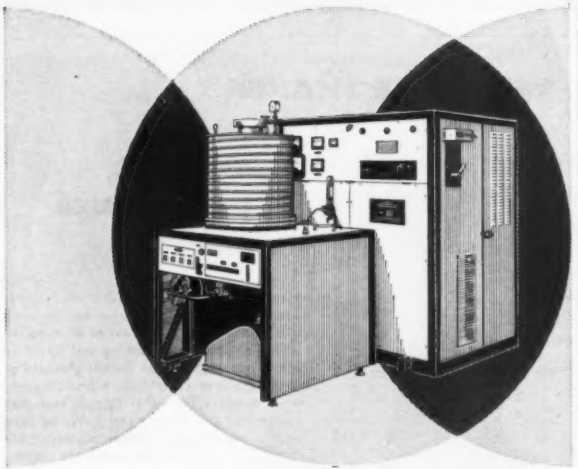

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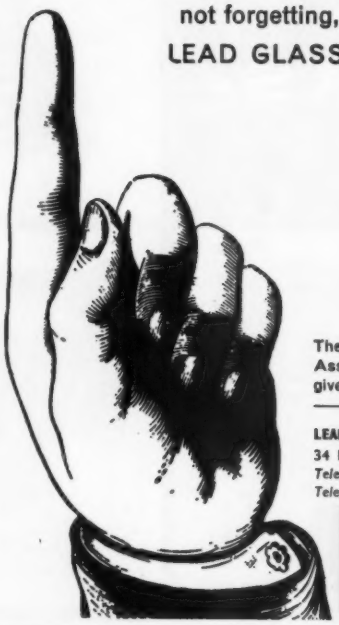

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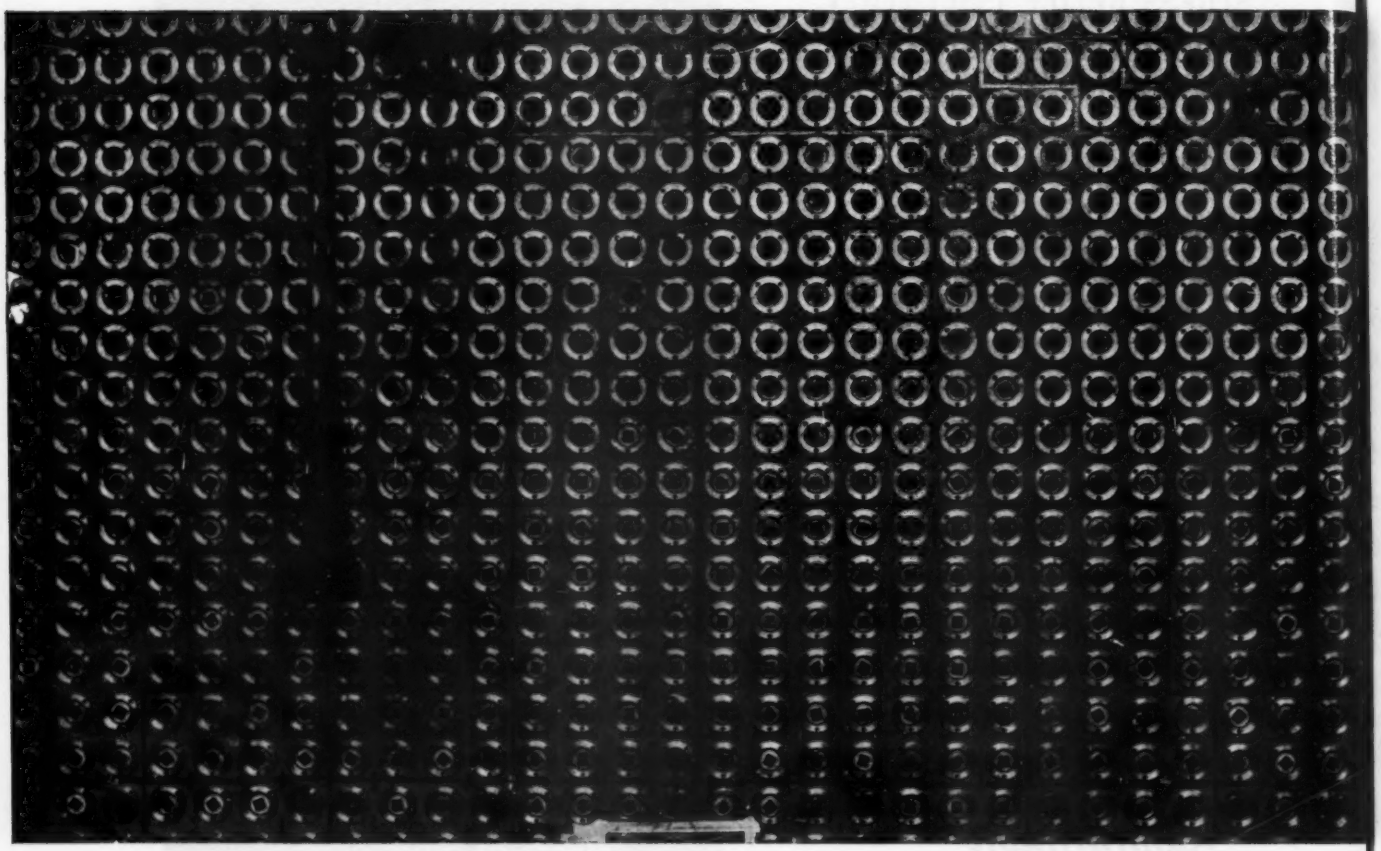

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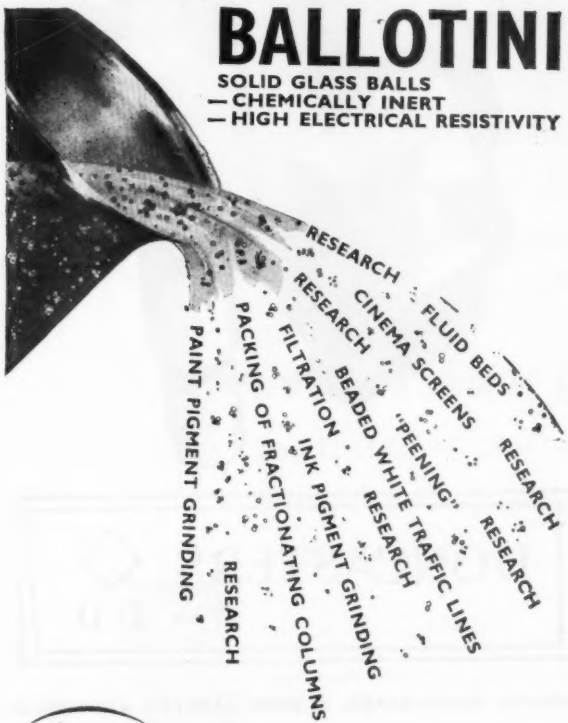

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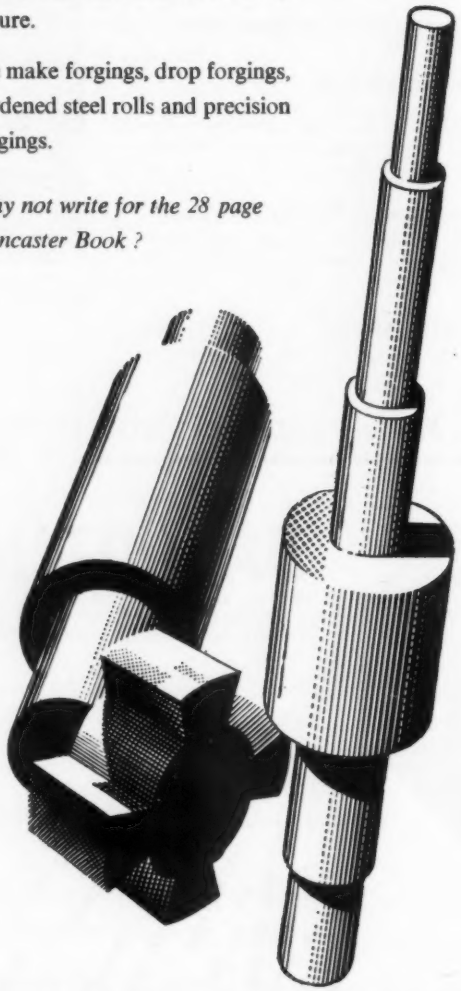

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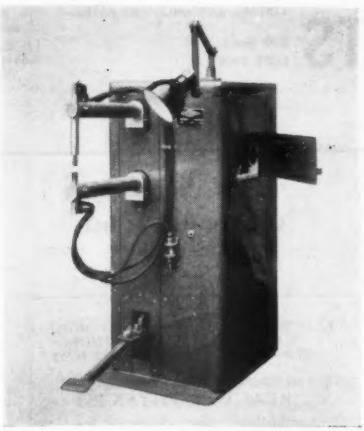

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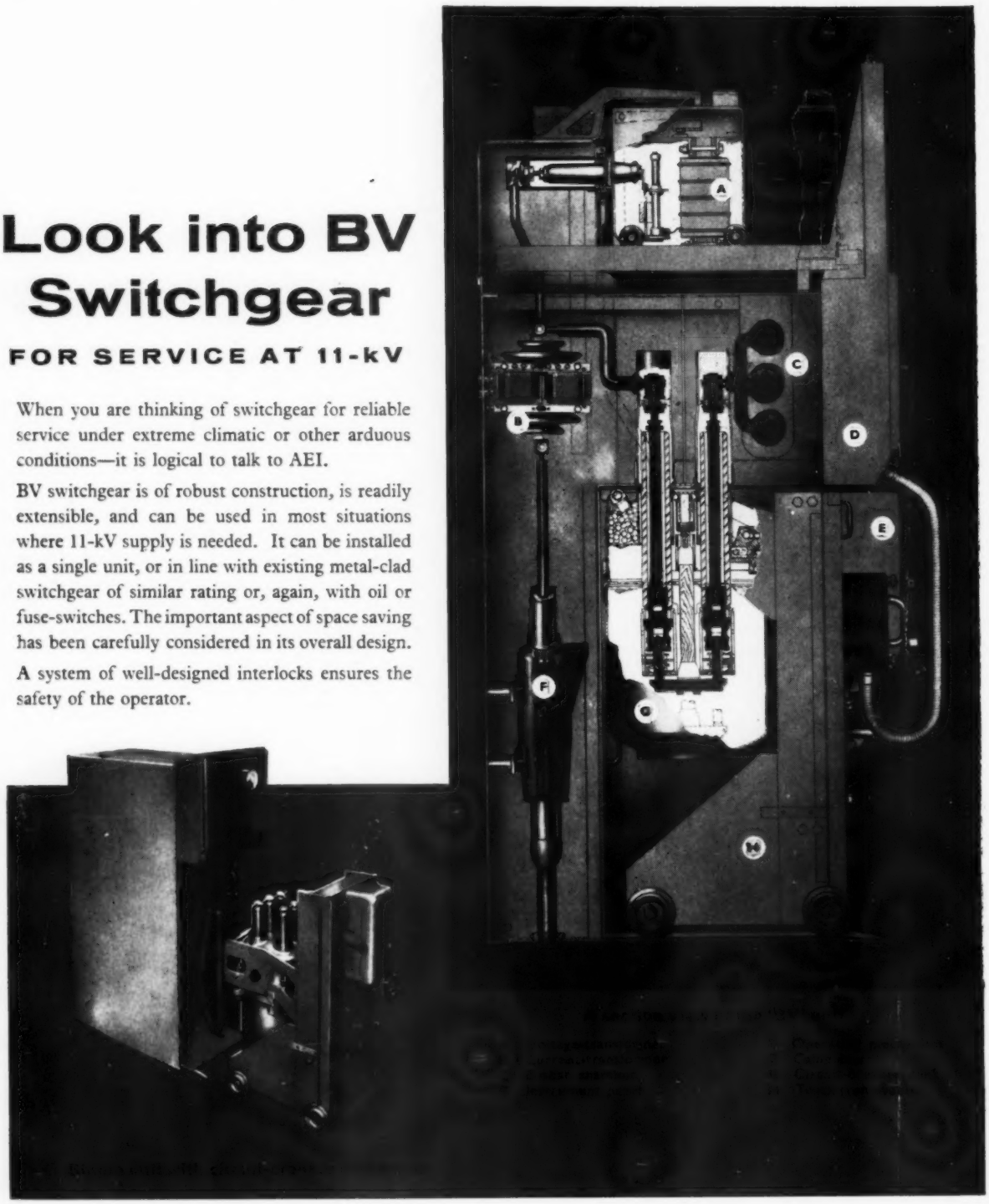

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